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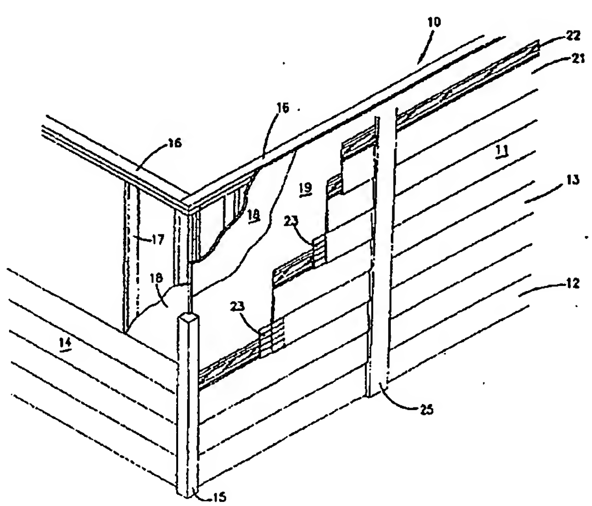
(54) Title: COMPOSITE SIDING SYSTEM AND METHODS OF MANUFACTURING AND INSTALLING SAME



(57) Abstract: A siding unit and method of manufacture and installation are disclosed. Each siding unit is a 2-part structure including a siding profile made of a thermoplastic-biofiber composite material and an upper flange made of a thermoplastic polymer. The upper flange is fastened to the siding profits.

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COMPOSITE SIDING SYSTEM AND METHODS OF MANUFACTURING AND INSTALLING SAME

This application is being filed as a PCT International Patent application on 12 January 2001, designating all countries, in the name of Andersen Corporation, a U.S. national corporation and resident, (Applicant for all countries except US); and Kurt Dalquist, Harold H. Evans, Giuseppe Puppin, Todd W. Bruchu and Kurt E. Heikkila, all U.S. citizens and residents (Applicants for US only).

Field of the Invention

The invention relates to an extruded or molded siding unit and siding systems made of a polymeric and fiber-polymeric composite material. The siding unit is adapted to be laid in overlapping courses to provide a weather-protective, ornamental exterior siding for houses and various other commercial and residential housings.

Background of the Invention

The exterior of houses and other structures are often protected by exterior siding products made of wood, vinyl, aluminum, bricks, stucco, and fiber reinforced composite materials such as wood fiber reinforced cement siding.

Brick has been a leading siding material for many years. Stucco has found significant use in new construction in the southern and western regions of the United States. Wood siding has also been a popular choice for many years. Traditional wood siding in a clapboard or shake is characterized by a tapered shape from a rather thick base portion to a rather thin upper edge. This design permits the siding to be nailed to the studs or other framing components of the house in overlapping relationship, in which the lower edge of each course overlaps the upper edge of the next lower course so as to shed rain.

Currently, aluminum, steel, hardboard, Masonite™, plywood and vinyl have dominated the siding market because of their lower cost as compared with brick, stucco or wood. Aluminum, steel, vinyl are favored due to low maintenance costs. These materials have been fabricated to simulate the shape and texture of the classic clapboards, wood shakes and shingles that consumers prefer.

The shapes and textures of the classic exterior surface materials produce attractive patterns of highlights and shadow lines on walls as the sun shifts in position during daylight.

Wood siding, while being attractive, requires periodic painting, staining or finishing. Wood siding may also be susceptible to insect attack if not finished properly. This type of siding may also experience uneven weathering for unfinished surfaces, and has a tendency to split, cup, check or warp. Wood shingle siding has the additional problem of being relatively slow to install. In addition, clear wood products are slowly becoming scarcer and are becoming more expensive.

In an effort to avoid these problems, aluminum siding was developed, and has enjoyed a widespread acceptance nationwide. Aluminum siding is normally made by a roll forming process and is factory painted or enameled so as to require substantially no maintenance during the life of the installation. However, metal siding tends to be energy inefficient and may transfer substantial quantities of heat.

More recently, rigid plastic material has been used as a substitute for aluminum siding, with the most typical siding material being made of a vinyl polymer, e.g. , polyvinyl chloride (PVC). Such plastic siding can be extruded in a continuous fashion or molded, after which lengths are cut to the desired length. Siding of this nature can be pigmented so as to be extruded or molded in the requisite color, thus avoiding the need for painting. However, it is difficult for the home-owner to refinish this type of siding in a different color.

While aluminum and plastic sidings have obvious advantages, such as a preformed surface finish and the elimination of maintenance, these siding choices pose certain inherent disadvantages. First, aluminum and plastic siding can be damaged when struck by a hard object such as stones, hail, or even a ladder which is carelessly handled. Repairing such dents in aluminum and plastic siding is difficult.

Conventional vinyl siding has an unattractive or unnatural softness or "give" to the touch," because extruded vinyl areas having less than about 0.100 of an inch in thickness are unduly flexible compared with the rigid look and feel of wood, stone, brick or stucco. As vinyl weathers, it becomes brittle. Thus, vinyl siding is more likely to crack or break as the siding ages.

In addition, most plastic and metal sidings are subject to "oil canning," i.e., surface distortions from temperature differences and unequal stress on different parts of the siding. These temperature differences cause unsightly bulges and depressions at the visible surface of the siding. Vinyl siding has a high coefficient of thermal expansion and contraction. In order to accommodate this and to achieve the desired protective coverage, an installer will often substantially overlap the vertical edges of vinyl siding. This causes noticeable, unattractive, outward bends in the ends of the overlapping end portions of the siding.

Moreover, conventional plastic siding often presents a poor imitation of wood textures and unattractive butt joints. Extruded vinyl siding often has a synthetic-appearing graining which is rolled into the extruded product after a partially congealed (solidified) "skin" has formed on the extruded product. Such a synthetic-appearing graining repeats itself at frequent intervals along the length of the vinyl siding. This frequent repetition is caused by a relatively short circumference around the hardened-steel roller die on which the makes the graining pattern. Consumers do not value such vinyl siding highly.

Fiber composite sidings including cellulosic fibers such as wood fiber and Kraft process paper fibers have been prepared by mixing the fibers with aqueous cement and clay slurries. The resulting fiber containing slurries are formed into planks and shakes by process technology similar to that used in the paper making industry. To form composite siding panels and planks, a liquid fiber-cement composite is rolled or pressed into the shape of the planks or panels, and then the green, de-watered, fiber-cement composite is cured. A typical siding cladding board and a cement containing formulation useful for making such siding boards are described in U.S. Patent Numbers 6,122,876 and 6,030,447 respectively.

Fiber-cement siding (FCS) products are installed by a siding contractor at a particular job site or a modular home manufacturer in a factory. To install FCS planks, for example, the planks are cut to a desired length and then nailed to plywood or wood-composite panels in a manner similar to hanging planks of cedar siding. After the FCS is installed, trim materials are generally attached to the structure. The FCS and the trim materials are then painted.

Fiber-cement composite siding (FCS) products offer several advantages compared to other types of siding materials. FCS is nonflammable, weatherproof, and relatively inexpensive to manufacture. Moreover, FCS does not rot and insects do not consume the fiber-cement composites. However FCS products must be maintained by painting. In addition, FCS is highly abrasive. It is often cut using abrasive disks, shear-like cutters and saws in a manner similar to cutting wood products with a hand-held power saw or a table saw. Cutting FCS frequently generates a very fine dust that creates an unpleasant working environment. Because fiber-cement composite materials are abrasive, cutters tend to wear out quickly.

Composite thermoplastic fiber materials have been used as a replacement for vinyl wood products. Such materials have enjoyed increasing utility in the prior art. A family of patents related to thermoplastic fiber composites are shown in U.S. Patent Nos. 5,441,801, 5,497,594, 5,539,027, 5,827,607, 5,932,334, 5,948,524, 6,004,668, 6,015,612 and 6,122,877 and others relating to thermoplastic composites using a biofiber such as a wood fiber in a high strength profile or structural member.

While the recent advances in thermoplastic composites using a wood fiber have improved the physical properties and appearance of fenestration products, special processing is required to manufacture these products. Producing a complex thermoplastic/wood composite profile is a complex and expensive process. If thermoplastic/wood composites are to be used as a replacement for vinyl wood products, the composite material must be capable of economic manufacture, ease of storage and transport and can be readily installed with simple hand tools in the field.

Accordingly, a substantial need exists for the development of a siding formed from a suitable composite material that can be directly formed by extrusion into reproducible, stable shapes advantageous for use as siding members. The siding structure must have resistance to weathering, relatively high strength and stiffness, an acceptable coefficient of thermal expansion, low thermal transmission, resistance to insect attack and rot, and a hardness and rigidity that permits sawing, milling, and fastener retention comparable to wood. The siding structure must be easily and economically formable and able to maintain reproducible stable dimensions, while

having the ability to be cut, milled, drilled and fastened at least as well as wooden members.

A substantial need exists for structurally strong, low life cycle cost, easily installed aesthetically pleasing siding systems.

Brief Discussion of the Invention

The invention includes a siding unit including a siding profile made of a thermoplastic-biofiber composite material and an upper flange fastened to the siding profile where the upper flange is made of a thermoplastic polymer.

The invention also includes a siding assembly for attachment to a building substrate, including a plurality of siding units, each siding unit having a siding profile made of a thermoplastic-biofiber composite material and an upper flange fastened to the siding profile where the upper flange is made of a thermoplastic polymer The siding assembly also includes a plurality of fasteners to fasten the siding units to a building substrate.

The invention also includes a siding unit formed by the process of fastening a thermoplastic-biofiber composite siding profile to a thermoplastic polymeric upper flange.

The invention further includes a method of manufacturing a siding unit including forming a siding profile, forming an upper flange and fastening the siding profile to the upper flange.

The invention further includes a method of installing siding including fastening a siding unit to a building substrate, each unit having a siding profile made of a thermoplastic-biofiber composite material and an upper flange fastened to the siding profile where the upper flange is made of a thermoplastic polymer.

The invention further includes building interface trim unit, including a elongated body having an inner face, an outer face, a first side edge and a second side edge parallel to the first side edge and having a serrated profile.

Brief Description of the Drawings

Figure 1A is a cross-sectional view of an embodiment of the upper flange.

Figure 1B is a cross-sectional view of an embodiment of the siding profile.

Figure 1C is a cross-sectional, end elevation view of a plurality of 2-part siding units, shown separately in Figure 1A and Figure 1B, installed on a building substrate.

Figure 1D is a front elevational view of the installed 2-part siding units shown in Figure 1C.

Figure 2A is a cross-sectional view of another embodiment of the upper flange.

Figure 2B is a cross-sectional view of another embodiment of the siding profile.

Figure 2C is a cross-sectional, end elevation view of a plurality of 2-part siding units, shown separately in Figure 2A and Figure 2B, installed on a building substrate.

Figure 2D is a front elevational view of the installed 2-part siding units shown in Figure 2C.

Figure 3A is a cross-sectional view of another embodiment of the upper flange.

Figure 3B is a cross-sectional view of another embodiment of the siding profile.

Figure 3C is a cross-sectional, end elevation view of a plurality of 2-part siding units, shown separately in Figure 3A and Figure 3B, installed on a building substrate.

Figure 3D is a front elevational view of the installed 2-part siding units shown in Figure 3C.

Figure 4A is a cross-sectional view of another embodiment of the upper flange.

Figure 4B is a cross-sectional view of another embodiment of the siding profile.

Figure 4C is a cross-sectional, end elevation view of a plurality of 2-part siding units, shown separately in Figure 4A and Figure 4B, installed on a building substrate.

Figure 4D is a front elevational view of the installed 2-part siding units shown in Figure 4C.

Figure 5A is a cross-sectional view of another embodiment of the upper flange.

Figure 5B is a cross-sectional view of another embodiment of the siding profile.

Figure 5C is a cross-sectional, end elevation view of a plurality of 2-part siding units, shown separately in Figure 5A and Figure 5B, installed on a building substrate.

Figure 5D is a front elevational view of the installed 2-part siding units shown in Figure 5C.

Figure 6A is a cross-sectional view of another embodiment of the upper flange.

Figure 6B is a cross-sectional view of another embodiment of the siding profile.

Figure 6C is a cross-sectional, end elevation view of a plurality of 2-part siding units, shown separately in Figure 6A and Figure 6B, installed on a building substrate.

Figure 6D is a front elevational view of the installed 2-part siding units shown in Figure 6C.

Figure 7A is a perspective view of an embodiment of a building interface trim piece.

Figure 7B is a side elevation view of the embodiment of a building interface trim piece shown in Figure 7A.

Figure 7C is the building interface trim piece view shown in Figure 7B assembled with a cross-sectional view of a cross-sectional, end elevation view of a plurality of 2-part siding units, shown in Figure 6C.

Figure 7D is an end elevation view of the embodiment of the building interface trim piece shown in Figure 7A.

Figure 7E is an end elevation view of an embodiment of an outside corner building interface trim piece shown in Figure 7A.

Figure 7F is an end elevation view of the embodiment of an inside corner building interface trim piece shown in Figure 7A.

Figure 7G is an end elevation view of the embodiment of another embodiment of a building interface trim piece shown in Figure 7A.

Figure 8A is a cross-sectional view of an embodiment of a spline.

Figure 8B is a front view of the embodiment of the spline shown in Figure 8A.

Figure 9A is a cross-sectional view of another embodiment of the spline.

Figure 9B is a front view of the embodiment of the spline shown in Figure 8B.

Figure 10 is a front view of two siding units butt-joined together with the spline shown in Figure 8A.

Figure 11 is a perspective view of a corner portion of a building having the siding of the present invention installed thereon, partially cutaway for viewing clarity.

Detailed Discussion of the Invention

The "siding profile" is defined as a profile that includes only one engagement channel for interlocking engagement with an adjacent siding unit. The siding profile is the lower part of a 2-part siding unit.

The "upper flange" is defined as a profile that includes only one engagement channel for interlocking engagement with an adjacent siding unit. The upper flange is the upper part of a 2-part siding unit.

The "engagement channel" is defined as a channel capable of interlocking with a second engagement channel. The engagement channel can be, for example, an "H" shaped channel, a "C" shaped channel, a "U" shaped channel or the like.

The "thermoplastic-biofiber composite material" is defined as material that is substantially composed of cellulosic fiber and thermoplastic polymer

wherein the thermoplastic forms a substantially continuous phase encapsulating a discontinuous fiber phase.

The "thermoplastic polymer" is defined as a synthetic high polymer that softens when heated above its glass transition temperature (T_g) but below its decomposition temperature (T_{Decomp}) and returns to its original condition with cooled to room temperature. "Thermoplastic Polymer" is also intended as thermoplastic polymer resins and/or mixtures thereof and/or thermoplastic copolymer resins which may or may not contain ingredients and/or additives including, but not limited to, stabilizers, lubricants, colorants, reinforcing particles, reinforcing fabric layers, laminates, surfacing layers, anti-foamants, anti-oxidants, fillers, foaming agents and/or other ingredients and/or additives for enhancing performance of the siding claimed herein.

The Coefficient of Thermal Expansion (COTE) of all materials is measured by the standard testing method ASTM D696.

All of the numerical values disclosed are modified by the term "about."

Figure 1A shows an embodiment of an upper flange 100. The upper flange 100 has an upper end 101 and a lower end 102. Near the lower end 102 is a receiver 125. The receiver 125 interlocks with an adjacent siding unit and is described further below. The receiver 125 has a "C" shape and is attached to the lower end 102 with a leg of the "C" shape. Between the point of attachment of the "C" shape and a terminus of the lower end 102, is an adjustment channel 135. The adjustment channel 135 allows an adjacent interlocking siding unit to be adjusted during installation. A lip 130 located at an unattached leg of the "C" shape. The lip 130 extends away from the lower end 102.

Between the adjustment channel 135 and the terminus of the lower end 102 is an overlap portion 110. The boundary between the adjustment channel 135 and overlap portion 110 is an offset 120. The offset 120 raises the overlap portion 110 above the adjustment channel 135 a distance that may be the thickness of a siding profile 150 as described below. Energy directors 115 may be on the overlap portion 110. The energy directors 115 project from a side of the overlap

portion 110. The energy directors 115 aid in thermal or ultrasonic fastening of the upper flange 100 to a siding profile 150 as described below.

A means for supporting 140 a second or adjacent siding profile 150 may be located at the upper end 101 of the upper flange 100. The means for supporting 140 provides physical support for a second or adjacent siding profile 150 to prevent the second or adjacent siding profile from failing. The means for supporting 140 can be an arch 145 structure. The arch 145 height is sufficient to provide physical support to a second or adjacent siding profile 150.

Figure 1B shows an embodiment of a siding profile 150. The siding profile 150 has an upper end 151 and a lower end 152. The siding profile 150 has a main body portion 165. The siding profile 150 has an inner surface 190 and an outer surface 195. The outer surface 195 of the main body portion 165 is exposed to the environment when installed. Near the lower end 152 is a nose 170. The nose 170 defines the boundary between the main body portion 165 and a bottom surface 175. The bottom surface 175 extends away from the nose 170 and creates a right or acute angle θ_1 between the inner surface 190 of the main body portion 165 and the inner surface 190 of the bottom surface 175. The bottom surface 175 extends to a rear leg 180. The rear leg 180 extends toward the upper end 151 and terminates at a lip 185. The lip 185 extends away from the inner surface 190. The main body portion 165, nose 170, bottom surface 175, rear leg 180 and lip 185 form a "U" shape and interlocks with the "C" shaped receiver 125 of an adjacent siding unit. The lip 185 and rear leg 180 interlocks the receiver 125 of an adjacent siding unit during installation as described below.

At the upper end 151 an offset 160 defines the boundary between a top edge 155 and the main body portion 165. The offset 160 lowers the top edge 155 below the main body portion 165 a distance that may be the thickness of the upper flange 100 as described below.

Figure 1C shows a side view of three 2-part siding units 103 installed on a building substrate 10 in overlapping horizontal courses. Each 2-part siding unit 103 includes the upper flange 100 shown in Figure 1A fastened to the siding profile 150 shown in Figure 1B. The upper flange 100 overlap portion 110 mates with

siding profile 150 top edge 155 and is secured or fastened together to form the 2-part siding unit 103.

The rear leg 180 and lip 185 of a first 2-part siding unit 103 engages the receiver 125 of a second 2-part siding unit 103 and interlocks the first 2-part siding unit 103 with the second 2-part siding unit 103. During installation, the directional alignment, both horizontal and vertical, of the second siding unit can be altered due to the adjustment channel 135 of the installed first siding unit. Alignment provides an even "reveal" of the siding profile. An even, "reveal" provides visually pleasing installed siding. Once aligned, the second siding unit can be fastened with a fastener 20 to the building substrate 10.

Drain holes 199 may be included on the lower end 152. Drain holes 199 allow water and debris to exit through the 2-part siding unit 103 to the environment. The drain holes 199 are located on at least a portion of the rear leg 180 or a portion of the bottom surface 175 so that the drain holes are not visible when the siding unit 103 is installed. The drain holes 199 may be any shape and have a surface area of at least 3/8 " square.

Figure 1C further shows the means for supporting 140 an adjacent 2-part siding unit 103. The means for supporting 140 is an arch 145 extending away from the building substrate 10 and the summit touching the inner surface 195 of the overlapping, adjacent siding profile 150. The arch 145 may define a cavity or be a solid structure 146. The solid structure can include porous material as described below.

Figure 1D shows a front view of the three 2-part siding units shown in Figure 1C. A protective layer or capstock layer 166 may be applied to the exposed portion or outer surface 195 of the main body portion 165. The upper flange 100 may have a plurality of elongated slots 111 arranged in a non-vertical order. The elongated slots 111 allow an installer flexibility to locate solid building substrate 10 to fasten the 2-part siding unit 103 with staples, nails, or the like (20). The elongated slots 111 also allow the 2-part siding unit 103 to move as the 2-part siding unit expands and contracts.

Figure 2A shows an embodiment of an upper flange 200. The upper flange 200 has an upper end 201 and a lower end 202. Near the lower end 202 is a

receiver 225. The receiver 225 interlocks with an adjacent siding unit and is described further below. The receiver 225 has a "C" shape and is attached to the lower end 202 with a leg of the "C" shape. Between the point of attachment of the "C" shape and a terminus of the lower end 202, is an adjustment channel 235. The adjustment channel 235 allows an adjacent interlocking siding unit to be adjusted during installation. A lip 230 located at an unattached leg of the "C" shape. The lip 230 extends away from the lower end 202.

Between the adjustment channel 235 and the terminus of the lower end 202 is an overlap portion 210. The boundary between the adjustment channel 235 and overlap portion 210 is an offset stop 220. The offset stop 220 is a ridge that raises above the adjustment channel 235 and overlap portion 210 a distance that may be the thickness of a siding profile 250 as described below. Energy directors (not shown) may be on the overlap portion 210 as was described above. The energy directors project from a side of the overlap portion 210. The energy directors aid in thermal or ultrasonic fastening of the upper flange 200 to a siding profile 250 as described below.

Figure 1B shows an embodiment of a siding profile 250. The siding profile 250 has an upper end 251 and a lower end 252. The siding profile 250 has a main body portion 265. The siding profile 250 has an inner surface 290 and an outer surface 295. The outer surface 295 of the main body portion 265 is exposed to the environment when installed. Near the lower end 252 is a nose 270. The nose 270 defines the boundary between the main body portion 265 and a bottom surface 275. The bottom surface 275 extends away from the nose 270 and creates a right or acute angle θ_2 between the inner surface 290 of the main body portion 265 and the inner surface 290 of the bottom surface 275. The bottom surface 275 extends to a rear leg 280. The rear leg 280 extends toward the upper end 251 and terminates at a lip 285. The lip 285 extends away from the inner surface 290. The main body portion 265, nose 270, bottom surface 275, rear leg 280 and lip 285 form a "U" shape and interlocks with the "C" shaped receiver 225 of an adjacent siding unit. The lip 285 and rear leg 280 interlocks the receiver 225 of an adjacent siding unit during installation as described below. At the upper end 251 is a top edge 255.

A means for supporting 240 the siding profile 250 may be located along the inner surface and extend away from the main body portion 265. The means for supporting 240 provides physical support to the siding profile 250 to prevent the siding profile 250 from failing. The means for supporting 240 can be a projection 245 structure. The projection 245 height is sufficient to provide physical support to the siding profile 250.

Figure 2C shows a side view of three 2-part siding units 203 installed on a building substrate 10 in overlapping horizontal courses. Each 2-part siding unit 203 includes the upper flange 200 shown in Figure 2A fastened to the siding profile 250 shown in Figure 2B. The upper flange 200 overlap portion 110 mates with siding profile 250 top edge 255 and is secured or fastened together to form the 2-part siding unit 203.

The rear leg 280 and lip 285 of a first 2-part siding unit 203 engages the receiver 225 of a second 2-part siding unit 203 and interlocks the first 2-part siding unit 203 with the second 2-part siding unit 203. During installation, the directional alignment of the second siding unit can be altered due to the adjustment channel 235 of the installed first siding unit. Once aligned, the second siding unit can be fastened with a fastener 20 to the building substrate 10.

Figure 2C further shows the means for supporting 240 the 2-part siding unit 103. The means for supporting 240 is a projection 245 extending away from the inner surface 295 of the siding profile 150 and the summit touching the building substrate 10. The projection 245 may define a cavity or be a solid structure. The solid structure can include porous material as described below.

Figure 2D shows a front view of the three 2-part siding units shown in Figure 2C. A protective layer or capstock layer 266 may be applied to the exposed portion or outer surface 295 of the main body portion 265. The upper flange 200 may have a plurality of elongated slots 211 arranged in a non-vertical order. The elongated slots 211 allow an installer flexibility to locate solid building substrate 10 to fasten the 2-part siding unit 203 with staples, nails, or the like (20). The elongated slots 211 also allow the 2-part siding unit 203 to move as the 2-part siding unit expands and contracts.

Figure 3A shows an embodiment of an upper flange 300. The upper flange 300 has an upper end 301 and a lower end 302. Near the lower end 302 is a receiver 325. The receiver 325 interlocks with an adjacent siding unit and is described further below. The receiver 325 has a "C" shape and is attached to the lower end 302 with a leg of the "C" shape. Between the point of attachment of the "C" shape and a terminus of the lower end 302, is an adjustment channel 335. The adjustment channel 335 allows an adjacent interlocking siding unit to be adjusted during installation. A lip 330 located at an unattached leg of the "C" shape. The lip 330 extends away from the lower end 302.

Between the adjustment channel 335 and the terminus of the lower end 302 is an overlap portion 310. The boundary between the adjustment channel 335 and overlap portion 310 is an offset 320. The offset 320 raises the overlap portion 310 above the adjustment channel 335 a distance that may be the thickness of a siding profile 350 as described below. Energy directors 315 may be on the overlap portion 310. The energy directors 315 project from a side of the overlap portion 310. The energy directors 315 aid in thermal or ultrasonic fastening of the upper flange 300 to a siding profile 350 as described below.

Figure 3B shows an embodiment of a siding profile 350. The siding profile 350 has an upper end 351 and a lower end 352. The siding profile 350 has a main body portion 365. The siding profile 350 has an inner surface 390 and an outer surface 395. The outer surface 395 of the main body portion 365 is exposed to the environment when installed. Near the lower end 352 is a nose 370. The nose 370 defines the boundary between the main body portion 365 and a bottom surface 375. The bottom surface 375 extends away from the nose 370 and creates a right or acute angle θ_2 between the inner surface 390 of the main body portion 365 and the inner surface 390 of the bottom surface 375. The bottom surface 375 extends to a rear leg 380. The rear leg 380 extends toward the upper end 351 and terminates at a lip 385. The lip 385 extends away from the inner surface 390. The main body portion 365, nose 370, bottom surface 375, rear leg 380 and lip 385 form a "U" shape and interlocks with the "C" shaped receiver 325 of an adjacent siding unit. The lip 385 and rear leg 380 interlocks the receiver 325 of an adjacent siding unit during installation as described below.

At the upper end 351 an offset 360 defines the boundary between a top edge 355 and the main body portion 365. The offset 360 lowers the top edge 355 below the main body portion 365 a distance that may be the thickness of the upper flange 300 as described below. A second offset 361 may also be provided also.

A means for supporting 340 the siding profile 350 may be located along the inner surface and extend away from the main body portion 365. The means for supporting 340 provides physical support to the siding profile 350 to prevent the siding profile 350 from failing. The means for supporting 340 can be a projection 345 structure. The projection 345 height is sufficient to provide physical support to the siding profile 350.

Figure 3C shows a side view of three 2-part siding units 303 installed on a building substrate 10 in overlapping horizontal courses. Each 2-part siding unit 303 includes the upper flange 300 shown in Figure 3A fastened to the siding profile 350 shown in Figure 3B. The upper flange 300 overlap portion 310 mates with siding profile 350 top edge 355 and is secured or fastened together to form the 2-part siding unit 303.

The rear leg 380 and lip 385 of a first 2-part siding unit 303 engages the receiver 325 of a second 2-part siding unit 303 and interlocks the first 2-part siding unit 303 with the second 2-part siding unit 303. During installation, the directional alignment of the second siding unit can be altered due to the adjustment channel 335 of the installed first siding unit. Once aligned, the second siding unit can be fastened with a fastener 20 to the building substrate 10.

Figure 3C further shows the means for supporting 340 the 2-part siding unit 303. The means for supporting 340 is a projection 345 extending away from the inner surface 395 of the siding profile 350 and the summit touching the building substrate 10. The projection 345 may define a cavity or be a solid structure. The solid structure can include porous material as described below.

Figure 3D shows a front view of the three 2-part siding units shown in Figure 3C. A protective layer or capstock layer 366 may be applied to the exposed portion or outer surface 395 of the main body portion 365. The upper flange 300 may have a plurality of elongated slots 311 arranged in a non-vertical

order. The elongated slots 311 allow an installer flexibility to locate solid building substrate 10 to fasten the 2-part siding unit 303 with staples, nails, or the like (20). The elongated slots 311 also allow the 2-part siding unit 303 to move as the 2-part siding unit expands and contracts.

Figure 4A shows an embodiment of an upper flange 400. The upper flange 400 has an upper end 401 and a lower end 402. Near the lower end 402 is a receiver 425. The receiver 425 interlocks with an adjacent siding unit and is described further below. The receiver 425 has a "C" shape and is attached to the lower end 402 with a leg of the "C" shape. Between the point of attachment of the "C" shape and a terminus of the lower end 402, is an adjustment channel 435. The adjustment channel 435 allows an adjacent interlocking siding unit to be adjusted during installation. A lip 430 located at an unattached leg of the "C" shape. The lip 430 extends away from the lower end 402.

Between the adjustment channel 435 and the terminus of the lower end 402 is an overlap portion 410. The boundary between the adjustment channel 435 and overlap portion 410 is an offset 420. The offset 420 raises the overlap portion 410 above the adjustment channel 435 a distance that may be the thickness of a siding profile 450 as described below. Energy directors 415 may be on the overlap portion 410. The energy directors 415 project from a side of the overlap portion 410. The energy directors 415 aid in thermal or ultrasonic fastening of the upper flange 400 to a siding profile 450 as described below.

Figure 4B shows an embodiment of a siding profile 450. The siding profile 450 has an upper end 451 and a lower end 452. The siding profile 450 has a main body portion 465. The siding profile 450 has an inner surface 490 and an outer surface 495. The outer surface 495 of the main body portion 465 is exposed to the environment when installed. Near the lower end 452 is a nose 470. The nose 470 defines the boundary between the main body portion 465 and a bottom surface 475. The bottom surface 475 extends away from the nose 470 and creates a right or acute angle θ_4 between the inner surface 490 of the main body portion 465 and the inner surface 490 of the bottom surface 475. The bottom surface 475 extends to a rear leg 480. The rear leg 480 extends toward the upper end 451 and terminates at a lip 485. The lip 485 extends away from the inner surface 490. The main body portion 465,

nose 470, bottom surface 475, rear leg 480 and lip 485 form a "U" shape and interlocks with the "C" shaped receiver 425 of an adjacent siding unit. The lip 485 and rear leg 480 interlocks the receiver 425 of an adjacent siding unit during installation as described below.

At the upper end 451 an offset 460 defines the boundary between a top edge 455 and the main body portion 465. The offset 460 lowers the top edge 455 below the main body portion 465 a distance that may be the thickness of the upper flange 400 as described below.

Figure 4C shows a side view of three 2-part siding units 403 installed on a building substrate 10 in overlapping horizontal courses. Each 2-part siding unit 403 includes the upper flange 400 shown in Figure 4A fastened to the siding profile 450 shown in Figure 4B. The upper flange 400 overlap portion 410 mates with siding profile 450 top edge 455 and is secured or fastened together to form the 2-part siding unit 403.

The rear leg 480 and lip 485 of a first 2-part siding unit 403 engages the receiver 425 of a second 2-part siding unit 403 and interlocks the first 2-part siding unit 403 with the second 2-part siding unit 403. During installation, the directional alignment of the second siding unit can be altered due to the adjustment channel 435 of the installed first siding unit. Once aligned, the second siding unit can be fastened with a fastener 20 to the building substrate 10.

Figure 4D shows a front view of the three 2-part siding units shown in Figure 4C. A protective layer or capstock layer 466 may be applied to the exposed portion or outer surface 495 of the main body portion 465. The upper flange 400 may have a plurality of elongated slots 411 arranged in a non-vertical order. The elongated slots 411 allow an installer flexibility to locate solid building substrate 10 to fasten the 2-part siding unit 403 with staples, nails, or the like (20). The elongated slots 411 also allow the 2-part siding unit 403 to move as the 2-part siding unit expands and contracts.

Figure 5A shows an embodiment of an upper flange 500. The upper flange 500 has an upper end 501 and a lower end 502. Near the lower end 502 is a receiver 525. The receiver 525 interlocks with an adjacent siding unit and is described further below. The receiver 525 has a "C" shape and is attached to the

lower end 502 with a leg of the "C" shape. Between the point of attachment of the "C" shape and a terminus of the lower end 502, is an adjustment channel 535. The adjustment channel 535 allows an adjacent interlocking siding unit to be adjusted during installation. A lip 530 located at an unattached leg of the "C" shape. The lip 530 extends away from the lower end 502.

Between the adjustment channel 535 and the terminus of the lower end 502 is an overlap portion 510. The boundary between the adjustment channel 535 and overlap portion 510 is an offset 520. The offset 520 raises the overlap portion 510 above the adjustment channel 535 a distance that may be the thickness of a siding profile 550 as described below. Energy directors 515 may be on the overlap portion 510. The energy directors 515 project from a side of the overlap portion 510. The energy directors 515 aid in thermal or ultrasonic fastening of the upper flange 500 to a siding profile 550 as described below.

A means for supporting 540 a second or adjacent siding profile 550 may be located at the upper end 501 of the upper flange 500. The means for supporting 540 provides physical support for a second or adjacent siding profile 550 to prevent the second or adjacent siding profile from failing. The means for supporting 540 can be a fin 545 structure. The fin 545 height is sufficient to provide physical support to a second or adjacent siding profile 550.

Figure 5B shows an embodiment of a siding profile 550. The siding profile 550 has an upper end 551 and a lower end 552. The siding profile 550 has a main body portion 565. The siding profile 550 has an inner surface 590 and an outer surface 595. The outer surface 595 of the main body portion 565 is exposed to the environment when installed. Near the lower end 552 is a nose 570. The nose 570 defines the boundary between the main body portion 565 and a bottom surface 575. The bottom surface 575 extends away from the nose 570 and creates an right or acute angle θ_5 between the inner surface 590 of the main body portion 565 and the inner surface 590 of the bottom surface 575. The bottom surface 575 extends to a rear leg 580. The rear leg 580 extends toward the upper end 551 and terminates at a lip 585. The lip 585 extends away from the inner surface 590. The main body portion 565, nose 570, bottom surface 575, rear leg 580 and lip 585 form a "U" shape and interlocks with the "C" shaped receiver 525 of an adjacent siding unit.

The lip 585 and rear leg 580 interlocks the receiver 525 of an adjacent siding unit during installation as described below.

At the upper end 551 an offset 560 defines the boundary between a top edge 555 and the main body portion 565. The offset 560 lowers the top edge 555 below the main body portion 565 a distance that may be the thickness of the upper flange 500 as described below.

Figure 5C shows a side view of three 2-part siding units 503 installed on a building substrate 10 in overlapping horizontal courses. Each 2-part siding unit 503 includes the upper flange 500 shown in Figure 5A fastened to the siding profile 550 shown in Figure 5B. The upper flange 500 overlap portion 510 mates with siding profile 550 top edge 555 and is secured or fastened together to form the 2-part siding unit 503.

The rear leg 580 and lip 585 of a first 2-part siding unit 503 engages the receiver 525 of a second 2-part siding unit 503 and interlocks the first 2-part siding unit 503 with the second 2-part siding unit 503. During installation, the directional alignment of the second siding unit can be altered due to the adjustment channel 535 of the installed first siding unit. Once aligned, the second siding unit can be fastened with a fastener 20 to the building substrate 10.

Figure 5C further shows the means for supporting 540 an adjacent 2-part siding unit 503. The means for supporting 540 is a fin 545 extending away from the building substrate 10 and the summit touching the inner surface 595 of the overlapping, adjacent siding profile 550. The fin 545 may define a cavity or be a solid structure 546. The solid structure can include porous material as described below.

Figure 5D shows a front view of the three 2-part siding units shown in Figure 5C. A protective layer or capstock layer 566 may be applied to the exposed portion or outer surface 595 of the main body portion 565. The upper flange 500 may have a plurality of elongated slots 511 arranged in a non-vertical order. The elongated slots 511 allow an installer flexibility to locate solid building substrate 10 to fasten the 2-part siding unit 503 with staples, nails, or the like (20). The elongated slots 511 also allow the 2-part siding unit 503 to move as the 2-part siding unit expands and contracts.

Figure 6A shows an embodiment of an upper flange 600. The upper flange 600 has an upper end 601 and a lower end 602. Near the lower end 602 is a receiver 625. The receiver 625 interlocks with an adjacent siding unit and is described further below. The receiver 625 has a "C" shape and is attached to the lower end 602 with a leg of the "C" shape. Between the point of attachment of the "C" shape and a terminus of the lower end 602, is an adjustment channel 635. The adjustment channel 635 allows an adjacent interlocking siding unit to be adjusted during installation. A lip 630 located at an unattached leg of the "C" shape. The lip 630 extends away from the lower end 602.

Between the adjustment channel 635 and the terminus of the lower end 602 is an overlap portion 610. The boundary between the adjustment channel 635 and overlap portion 610 is an offset 620. The offset 620 raises the overlap portion 610 above the adjustment channel 635 a distance that may be the thickness of a siding profile 650 as described below. Energy directors 615 may be on the overlap portion 610. The energy directors 615 project from a side of the overlap portion 610. The energy directors 615 aid in thermal or ultrasonic fastening of the upper flange 600 to a siding profile 650 as described below.

Figure 6B shows an embodiment of a siding profile 650. The siding profile 650 has an upper end 651 and a lower end 652. The siding profile 650 has a main body portion 665. The siding profile 650 has an inner surface 690 and an outer surface 695 that define a cavity 653. The outer surface 695 of the main body portion 665 is exposed to the environment when installed. Near the lower end 652 is a nose 670. The nose 670 defines the boundary between the main body portion 665 and a bottom surface 675. The bottom surface 675 extends away from the nose 670 and creates a right or acute angle θ_6 between the inner surface 690 of the main body portion 665 and the inner surface 690 of the bottom surface 675. The bottom surface 675 extends to a rear leg 680. The rear leg 680 extends toward the upper end 651 and terminates at a lip 685. The lip 685 extends away from the inner surface 690. The main body portion 665, nose 670, bottom surface 675, rear leg 680 and lip 685 form a "U" shape and interlocks with the "C" shaped receiver 625 of an adjacent siding unit. The lip 685 and rear leg 680 interlocks the receiver 625 of an adjacent siding unit during installation as described below.

At the upper end 651 an offset 660 defines the boundary between a top edge 655 and the main body portion 665. The offset 660 lowers the top edge 655 below the main body portion 665 a distance that may be the thickness of the upper flange 600 as described below.

Figure 6C shows a side view of three 2-part siding units 603 installed on a building substrate 10 in overlapping horizontal courses. Each 2-part siding unit 603 includes the upper flange 600 shown in Figure 6A fastened to the siding profile 650 shown in Figure 6B. The upper flange 600 overlap portion 610 mates with siding profile 650 top edge 655 and is secured or fastened together to form the 2-part siding unit 603.

The rear leg 680 and lip 685 of a first 2-part siding unit 603 engages the receiver 625 of a second 2-part siding unit 603 and interlocks the first 2-part siding unit 603 with the second 2-part siding unit 603. During installation, the directional alignment of the second siding unit can be altered due to the adjustment channel 635 of the installed first siding unit. Once aligned, the second siding unit can be fastened with a fastener 20 to the building substrate 10.

Figure 6C further shows the means for supporting 640 a 2-part siding unit 603. The means for supporting 640 is a bridge 654a extending between the main body portion 265 and the inner surface 690 or material 654b at least partially filling the cavity 653. The bridge 654a or material 654b can be formed from solid, porous or foamed material as described below.

Figure 6D shows a front view of the three 2-part siding units shown in Figure 6C. A protective layer or capstock layer 666 may be applied to the exposed portion or outer surface 695 of the main body portion 665. The upper flange 600 may have a plurality of elongated slots 611 arranged in a non-vertical order. The elongated slots 611 allow an installer flexibility to locate solid building substrate 10 to fasten the 2-part siding unit 103 with staples, nails, or the like (20). The elongated slots 611 also allow the 2-part siding unit 603 to move as the 2-part siding unit expands and contracts.

Figure 7A shows an embodiment of a building interface trim unit 700. The building interface trim unit 700 includes an outer surface 705 and an inner surface 710. A first side edge 715 runs along the inner surface. A second side edge

720 runs parallel to the first side edge 715. The second side edge 720 had a serrated profile 725 to mate with the 2-part siding unit's siding profile 150, 250, 350, 450, 550, 650 when installed on a building 10. The building interface trim unit 700 can be planar as shown or be oriented to provide an inside or outside corner. The building interface trim unit 700 can be formed by molding or extrusion.

The building interface trim unit 700 provides a barrier to a substantial portion of environmental water. The building interface trim unit 700 allows for some environmental water to pass by the serrated profile 725. Water that enters the building interface trim unit 700 is directed out of the building interface trim unit 700 via drainage channels 730. The building interface trim unit 700 can be made of conventional fenestration materials or materials disclosed herein to make the components of the 2-part siding units.

Figure 7B is a side elevation view of the embodiment of a building interface trim piece shown in Figure 7A. The building interface trim unit 700 includes an outer surface 705 and an inner surface 710. A first side edge 715 runs along the inner surface. A second side edge 720 runs parallel to the first side edge 715. The second side edge 720 had a serrated profile 725 to mate with the 2-part siding unit's siding profile 150, 250, 350, 450, 550, 650 when installed on a building 10.

Figure 7C is the building interface trim piece view shown in Figure 7B assembled with a cross-sectional view of a cross-sectional, end elevation view of a plurality of 2-part siding units, shown in Figure 6C. The building interface trim unit 700 is adapted to mate with any overlapping siding assemblies.

Figure 7D is an end elevation view of the embodiment of the building interface trim piece shown in Figure 7A. The building interface trim unit 700 includes an outer surface 705 and an inner surface 710. A first side edge 715 runs along the inner surface. A second side edge 720 runs parallel to the first side edge 715. The second side edge 720 had a serrated profile 725 to mate with the 2-part siding unit's siding profile 150, 250, 350, 450, 550, 650 when installed on a building 10.

Figure 7E is an end elevation view of an embodiment of an outside corner building interface trim piece shown in Figure 7A. The building interface trim

unit 700 includes an outer surface 705 and an inner surface 710. A first side edge 715 runs along the inner surface. A second side edge 720 runs parallel to the first side edge 715. The second side edge 720 had a serrated profile 725 to mate with the 2-part siding unit's siding profile 150, 250, 350, 450, 550, 650 when installed on a building 10.

Figure 7F is an end elevation view of the embodiment of an inside corner building interface trim piece shown in Figure 7A. The building interface trim unit 700 includes an outer surface 705 and an inner surface 710. A first side edge 715 runs along the inner surface. A second side edge 720 runs parallel to the first side edge 715. The second side edge 720 had a serrated profile 725 to mate with the 2-part siding unit's siding profile 150, 250, 350, 450, 550, 650 when installed on a building 10.

Figure 7G is an end elevation view of the embodiment of another embodiment of a building interface trim piece shown in Figure 7A. The building interface trim unit 700 includes an outer surface 705 and an inner surface 710. A first side edge 715 runs along the inner surface. A second side edge 720 runs parallel to the first side edge 715. The second side edge 720 had a serrated profile 725 to mate with the 2-part siding unit's siding profile 150, 250, 350, 450, 550, 650 when installed on a building 10.

Figure 8A is side view of an embodiment of a spline 800. The spline 800 is a means for joining adjacent siding units. The spline 800 spans two adjacent 2-part siding units to form a butt-joint. The spline 800 is sized and configured to fit against an inner surface of the siding profile. The spline 800 may include energy directors 815 located along the length of the spline 800 on the spline member 805. The energy directors 815 aid in thermal or ultrasonic fastening of the spline 800 to a siding profile. The spline 800 includes a lower portion 810 that is sized and configured to fit within a lower engagement channel of a siding profile. The spline 800 can add structural strength to the butt-joint. The spline can be made of thermoplastic or thermoplastic-biofiber material.

Figure 8B is a front view of the embodiment shown in Figure 8A. The spline 800 includes a spline member 805 and a lower portion 810 as described above.

Figure 9A is a side view of another embodiment of a spline 900. The spline 900 is a means for joining adjacent siding units. The spline 900 spans two adjacent 2-part siding units to form a butt-joint. The spline 900 is sized and configured to fit against an inner surface of the siding profile. The spline 900 may include energy directors 915 located along the length of the spline 900 on the spline member 905. The energy directors 915 aid in thermal or ultrasonic fastening of the spline 900 to a siding profile. The spline 900 includes a lower portion 910 that is sized and configured to fit within a lower engagement channel of a siding profile. The spline 900 can add structural strength to the butt-joint. The spline can be made of thermoplastic or thermoplastic-biofiber material. The lower portion 910 may be mode out of thermoplastic, thermoplastic-biofiber, metal or other material that provides a sufficient tensile strength to provide structural support to the butt-joint, such as, for example, metal rods.

Figure 9B is a front view of the embodiment shown in Figure 9A. The spline 900 includes a spline member 905 and a lower portion 910 as described above.

Figure 10 is a front view of two 2-part siding units butt-joined together 1000. Each 2-part siding unit 1001 includes a upper flange 1005 and a siding profile 1010. A spline 1020 is secured to a portion of each siding profile 1010. The spline is secured to an inner surface of the siding profile 1010 so that it is not visible when installed. The upper flange may have a plurality of elongated slots 1011 arranged in a non-vertical order. The elongated slots 1011 can be arranged in any order as illustrated in Figure 10.

Figure 11 depicts framing construction in a house or similar building substrate 10 in which the inventive siding system is installed on the exterior surface. Although the invention is applicable to buildings and structures of all types, it will be described for convenience and ease of description relative to a house.

The house 10 is covered by a plurality of elongated, horizontal 2-part siding units 11. The 2-part siding units 11 may be installed on all of the exterior wall surfaces 12 of the house. The house 10 has a side wall 13 and an end wall 14. A outside corner of the building between the walls 13, 14 has a concave vertical

building interface trim unit 15. The house may also have a planar vertical building interface trim unit 25 along the side wall 13.

Ceiling or header joists 16 and wall studs 17 make up a portion of the house's frame structure. The header 16 and studs 17 may be made of wood (as shown) or may be made from aluminum channels or steel channels, or other structural, load-supporting members. The wall structure includes a sheathing layer 18, such as a layer of plywood, particleboard, or other suitable sheathing or structural layer. This sheathing layer 18 is secured to the studs 17 and header 16. Over the sheathing layer 18 is a water or air barrier sheet layer 19, for example, comprised of asphalt-impregnated building felt paper, or a non-woven housewrap material, such as TYVEK™ available from E.I. DuPont Inc., or the like. The lower part of each 2-part siding unit's siding profile portion 21 overlaps and covers the upper flange 22 of the next lower 2-part siding unit 11, and the 2-part siding units are in hook engagement as will be described below.

Two 2-part siding units 11 can be butt-joined with a spline 23. The spline 23 can be installed before the 2-part siding unit 11 is installed. The spline 23 may be secured to the 2-part siding units 11 forming a solid butt-joint.

When the siding system is installed on the building 10, a starter trim strip (not shown) is first fastened on the bottom periphery of each side of the house 10. The strip may be a conventional "J-channel" formed with its own nailing flange shown in detail below. After the starter strip is secured in place, a first course 12 of 2-part siding is installed horizontally along the width of a wall surface of the house 10. The lower edge of each elongated 2-part siding unit 12 is dropped into the U-channel in the starter strip, and the 2-part siding unit 12 is secured in place against the house 10 by a plurality of fasteners 20 driven through the slots in the upper flange. Then, a second and successive courses of 2-part siding units 11 are similarly installed in place. A vertical building interface trim piece 15 covers the corner joint.

When the course of 2-part siding units 11 reach the top of a wall surface, a building interface trim unit or accessory strip (not shown) is provided, which either caps off the siding system on that side of the house or provides a connection between the vertical wall surface and the other surfaces of the side, such as the soffit, overhang or fascia (not shown). Building interface trim units can be

used to finish off the building surfaces on the edges, corners and around windows and doors.

2-Part Siding Structure

The siding structure of the invention is a 2-part siding unit that includes a siding profile and an upper flange. The upper flange and siding profile can be separately formed and subsequently joined together to form the 2-part siding unit. Since the siding profile and upper flange each have a single engagement channel, a final siding unit includes both a siding profile and upper flange joined together. This 2-part siding unit is capable of interlocking with a second adjacent siding unit. The upper flange engagement channel may engage and interlock with the siding profile engagement channel of an adjacent two-part siding unit as the 2-part siding units are installed on a building substrate. The upper flange may be fastened to the siding profile in a continuous or intermittent fashion.

The upper flange and siding profile can have different physical properties. The upper flange may have a coefficient of thermal expansion (COTE) greater than the COTE for the siding profile. The upper flange's COTE may be 1.5 times, 2 times or greater than the siding profile's COTE. Bonding two materials together with different COTEs causes material deformation or deflection at the boundary of the two materials as the temperature changes. Bimetal thermometers commonly illustrate this concept. Surprisingly, a siding unit formed by joining two materials with such different COTEs provides many advantages and negligible COTE deformation problems.

The 2-part siding unit may include means for supporting the siding profile or an adjacent siding profile as described above. The means for supporting functions to absorb static and dynamic impact forces directed at the siding unit. The means for supporting can be located between the siding profile and building substrate when installed on a building substrate. The means for supporting can be made of any material or combination of materials for example, thermoplastic polymer, thermoplastic-biofiber composite material, or foams. The means for supporting can be any shape or structure for example, an arch, a fin, or a projection. The means for supporting prevents the 2-part siding unit from fracturing (failing) on either a micro or macroscopic level, when impacted by environmental or incidental

contacts such as, for example, projectile, hail, ladders, and utility or construction work.

Upper Flange

The upper flange can be a thermoplastic polymer. The thermoplastics can include polyolefins such as polyethylene, polypropylene or other thermoplastic polymers such as polyvinyl chloride, polystyrene, polyacrylic materials, polyester materials and other common thermoplastics. Thermoplastic polymers can be extruded into complex profiles economically.

The upper flange may not be exposed to the environment, thus the material selected to form the upper flange can be a lower grade thermoplastic or less costly material since it may not be exposed to sunlight or weathering. The upper flange may not require a protective capstock coating since the upper flange may not be exposed to the environment. Thus, the material used to form the upper flange can be selected based on the material strength, flexibility, ease of extrusion and low material cost.

The thickness of the upper flange can range from 0.6 to 1.9 mm (0.025 to 0.075 inch) and all numerical values subsumed therein or 1.3 mm (0.05 inch). The upper flange COTE can range from 4.5×10^{-5} m/m/°C (2.5×10^{-5} in/in/°F) to 6×10^{-5} m/m/°C (3.4×10^{-5} in/in/°F) and all numerical values subsumed therein.

The upper flange may include energy directors on the overlap portion. The energy directors can be formed of the same material as the upper flange. Energy directors are projections that focus the energy used to secure the upper flange to the siding profile and aid in fastening the upper flange to the siding profile. One or more energy directors may be provided. The energy director may be continuous or intermittent along the length of the upper flange. The energy directors can be any shape and may be 0.4 mm (0.015 inch) high and 0.5 mm (0.02 inch) wide.

The upper flange may have a plurality of elongated slots arranged in a non-vertical order. The elongated slots allow an installer flexibility to locate solid building substrate to fasten the 2-part siding unit with staples, nails, or the like. The elongated slots also allow the 2-part siding unit to move as the 2-part siding unit expands and contracts.

Siding profile

The siding profile can be a composite of a thermoplastic polymer and a biofiber; however, the siding profile may be a thermoplastic polymer material alone. The thermoplastics can include polyolefins such as polyethylene, polypropylene or other thermoplastic polymers such as polyvinyl chloride, polystyrene, polyacrylic materials, polyester materials and other common thermoplastics. The biofiber may include any cellulosic fibers such as wood fibers. In contrast to vinyl siding, as the biofiber-thermoplastic composite weathers, the ductility of the material improves.

The siding profile can be a solid "open" profile or a hollow profile. The hollow profile can be at least partially filled with a foam or have "bridges" that form a web structure within the hollow profile. The bridges can be solid or a foam material. The thickness of the solid siding profile can range from 2.5 to 3.8 mm (0.1 to 0.15 inch) and all numerical values subsumed therein or 3.2 mm (0.12 inch). The siding profile COTE can range from 4.5×10^{-5} m/m/°C (2.5×10^{-5} in/in/°F) to 3×10^{-5} m/m/°C (1×10^{-5} in/in/°F) and all numerical values subsumed therein. The siding profile can be a single (see Figure 1), double (see Figure 5) or more, faced profile.

A thermoplastic-biofiber composite combines 10 to 50, and all numerical values subsumed therein, parts of a polyolefin such as a polyethylene or polypropylene homopolymer or copolymer with greater than 50 to 90, and all numerical values subsumed therein, parts of a fiber having an aspect ratio greater than 2. Useful polyolefin material is a polyethylene or polypropylene polymer having a melting point of 140 to 160°C or 145 to 158°C. The polyethylene material can be, for example, a polyethylene homopolymer or copolymer with 0.01 to 10wt% of a C_{2-16} olefin monomer. The polypropylene material can be, for example, a polypropylene homopolymer or copolymer with 0.01 to 10 wt% of ethylene or a C_{4-16} olefin monomer or mixtures thereof. This polymer can have a melt flow index of less than 1.0 g-10 min^{-1} or 0.5 g-10 min^{-1} when extruded or from 2 to 20 g-10 min^{-1} when the composite is injection molded. The melt flow index is determined in accord with ASTM 1238.

The composite can also compatibilized using a compatibilizing agent that promotes the desired intimate contact between polymer and fiber whereby fiber

particles are encapsulated by a continuous polymer phase. The biofiber can be dried to a content of less than 5000 parts, or less than 3500 parts of water per each million parts (ppm) of fiber to promote the encapsulated morphology which applicants believe results from opening fiber cellular structure to wetting and penetration by fluidized thermoplastic polymer. The combination of these factors results in a composite having surprisingly improved structural and thermal properties. A representative polypropylene random copolymer is Montell SV-258. Representative compatibilizers are Eastman Epolene™ Series – E43, G3003, G0315, etc.

The composite can also include a polyvinyl chloride and biofiber composite. Polyvinyl chloride (PVC) is a common commodity thermoplastic polymer that can be used in the composite. PVC homopolymers in a variety of molecular weights (K values) are readily available from a number of sources, GEON and Shin-Tech, for example. Polyvinyl chloride can also be combined with other vinyl monomers in the manufacture of polyvinyl chloride copolymers. Such copolymers can be linear copolymers, branched copolymers, graft copolymers, random copolymers, regular repeating copolymers, block copolymers, etc. Monomers that can be combined with vinyl chloride to form vinyl chloride copolymers include a acrylonitrile; alpha-olefins such as ethylene, propylene, etc.; chlorinated monomers such as vinylidene dichloride, acrylate monomers such as acrylic acid, methylacrylate, methylmethacrylate, acrylamide, hydroxyethyl acrylate, and others; styrenic monomers such as styrene, alphamethyl styrene, vinyl toluene, etc.; vinyl acetate; and other commonly available ethylenically unsaturated monomer compositions.

Such monomers can be used in an amount up to 50 mol-%, the balance being vinyl chloride. Polymer blends or polymer alloys can be useful in manufacturing the pellet or linear extrudate of the invention. Such alloys comprise two miscible polymers blended to form a uniform composition. Scientific and commercial progress in the area of polymer blends has lead to the realization that important physical property improvements can be made not by developing new polymer material but by forming miscible polymer blends or alloys. A polymer alloy at equilibrium comprises a mixture of two amorphous polymers existing as a single phase of intimately mixed segments of the two macro molecular components.

Miscible amorphous polymers form glasses upon sufficient cooling and a homogeneous or miscible polymer blend exhibits a single, composition dependent glass transition temperature (T_g). Immiscible or non-alloyed blend of polymers display two or more glass transition temperatures associated with immiscible polymer phases. In the simplest cases, the properties of polymer alloys reflect a composition weighted average of properties possessed by the components. In general, however, the property dependence on composition varies in a complex way with a particular property, the nature of the components (glassy, rubbery or semicrystalline), the thermodynamic state of the blend, and its mechanical state whether molecules and phases are oriented. Polyvinyl chloride forms a number of polymer alloys including, for example, polyvinyl chloride/nitrile rubber; polyvinyl chloride and related chlorinated copolymers and terpolymers of polyvinyl chloride or vinylidene dichloride polyvinyl chloride/alphamethyl styrene-acrylonitrile copolymer blends; polyvinyl chloride/polyethylene; polyvinyl chloride/chlorinated polyethylene and others.

The primary requirement for the substantially thermoplastic polymeric material is that it retain sufficient thermoplastic properties to permit melt blending with wood fiber, permit formation of linear extrudate pellets, and to permit the composition material or pellet to be extruded or injection molded. Useful PVC resin blends (including foaming agent and stabilizers) and extrusion conditions therefore are described by Suzuki et al. in U.S. Patent No. 5,712,319 the disclosure of which is hereby incorporated by reference.

A variety of biofiber materials can be used in the composites of the invention. Such fibers are fibers of naturally occurring sources that have significant aspect ratio to provide structural properties of the composite. Such fibers include wood fiber, flax, cotton, bagasse, wood flour, straw, recycled fiber, pulp, or other cellulosic material, etc. Wood fiber, in terms of abundance and suitability can be derived from either soft woods or evergreens or from hard woods commonly known as broad leaf deciduous trees. Soft woods are generally preferred for fiber manufacture because the resulting fibers are longer, contain high percentages of lignin and lower percentages of hemicellulose than hard woods. While soft wood is a primary source of fiber for the invention, additional fiber make-up can be derived

from a number of secondary or fiber reclaim sources including bamboo, flax, rice, sugar cane, and recycled fibers from newspapers, boxes, computer printouts, etc.

However, the primary source for wood fiber includes the wood fiber by-product of sawing or milling soft woods commonly known as sawdust or milling tailings. Such wood fiber has a regular reproducible shape and aspect ratio. The fibers based on a random selection of 100 fibers are commonly at 0.1 to 3 mm in length, 0.05 to 1 mm in thickness and commonly have an aspect ratio of at least 1.8, or 2.5 to 7.0. The preferred fiber is derived from processes common in the manufacture of windows and doors. Wooden members are commonly ripped or sawed to size in a cross grain direction to form appropriate lengths and widths of wood materials. The by-product of such sawing operations is a substantial quantity of sawdust. In shaping a regular shaped piece of wood into a useful milled shape, wood is passed through machines which selectively removes wood from the piece leaving the useful shape. Such milling operations produce substantial quantities of sawdust or mill tailing by-products. Furthermore, substantial waste trim is produced when shaped materials are cut to size and subsequently have mitered joints, butt joints, overlapping joints, mortise and tenon joints formed therein. Such process produce large trim pieces which can comminuted by well-known methods to form wood fiber having dimensions approximating sawdust or mill tailings. Blending of wood fibers with other biofibers (all of which may have different particle sizes and particle size distributions) is envisioned. Alternatively, the fiber stream can be pre-sized, or can be sized after blending, to yield input fiber have a preferred size and size distribution. Finally, the fiber can be pre-pelletized before use in composite manufacture.

Frequently the waste trim pieces and sawdust material contains substantial proportions of other materials used to make wood sashes and frames for windows and doors including, but not limited to, for example, polyvinyl chloride or other polymer materials that have been used as coating, cladding or envelope on wooden members (10 wt %); recycled structural members made from thermoplastic materials; polymeric materials from coatings; adhesive components in the form of hot melt adhesives, solvent based adhesives, powdered adhesives, etc.; paints including water based paints, alkyd paints, epoxy paints, etc.; preservatives, anti-

fungal agents, anti-bacterial agents, insecticides, etc., and other non-wood materials (ONWM) used in the manufacture of wooden doors and windows. The ONWM content is less than 25 wt-% of the total biofiber input into a preferred polyvinyl chloride wood fiber product. The intentional recycle ranges from 1 to 25 wt-% or 2 to 20 wt-% or 3 to 15 wt-% recyclable ONWM based on the weight of input biofiber.

In manufacturing the thermoplastic-biofiber composite, the thermoplastic and fiber are blended, often in dry form, and then introduced into an extruder in which the materials are intimately blended, melted and formed into a composite material as described in greater detail hereinbelow. Often, the structural components are directly extruded from the initial blending of these materials or can be first extruded in the form of a pellet which then can be introduced, in turn, into a profile forming extruder device at a later time or different location.

The thermoplastic resin and biofiber can be combined and formed into a pellet using thermoplastic extrusion processes. Fiber can be introduced into pellet making process in a number of sizes. The biofiber (when wood fiber) should have a minimum length of at least 0.1 mm because wood flour tends to be explosive at certain wood to air ratios. Further, wood fiber of appropriate size of an aspect ratio greater than 1, or greater than 2, tends to increase the physical properties of the extruded structural member. However, useful structural members can be made with a fiber of very large size. Fibers that are of reinforcing length up to 3 cm in length and 0.5 cm in thickness can be used as input to the pellet or linear extrudate manufacturing process. However, particles of this size do not produce highest quality structural members or maximized structural strength. The best appearing product with maximized structural properties are manufactured within a range of particle size as set forth below. Further, large particle wood fiber an be reduced in size by grinding and screening sifting or other similar processes that produce a fiber similar to sawdust having the stated dimensions and aspect ratio. One further advantage-of manufacturing sawdust of the desired size is that the material can be pre-dried before introduction into the pellet or linear extrudate manufacturing process. Further, the wood fiber can be pre-pelletized into pellets of wood fiber with small amounts of binder if necessary.

During the pelletizing process for the composite pellet, the thermoplastic resin and fiber are intimately contacted at high temperatures and pressures to insure that the fiber and polymeric material are wetted, mixed and extruded in a form such that the polymer material, on a microscopic basis, coats and flows into the pores, cavity, etc., of the fibers. During the extrusion process, the fibers are substantially longitudinally oriented into the extrusion direction by the extrudate flow profile. Such substantial orientation causes overlapping of adjacent parallel fibers and polymeric coating of the oriented fibers resulting a reinforced material that has substantially improved mechanical properties such as tensile strength, coefficient of thermal expansion, and a modulus of elasticity.

Moisture control is an element of manufacturing a useful linear extrudate or pellet. Depending on the equipment used and processing conditions, control of the water content of the linear extrudate or pellet can be important in forming a successful structural member substantially free of internal voids or surface blemishes. The concentration of water present in the biofiber during the formation of pellet or linear extrudate when heated can flash from the surface of the newly extruded structural member and can come as a result of a rapid volatilization, form a steam bubble deep in the interior of the extruded member which can pass from the interior through the hot thermoplastic extrudate leaving a substantial flaw. In a similar fashion, surface water can bubble and leave cracks, bubbles or other surface flaws in the extruded profile or member. Fiber sources when harvested, depending on relative humidity and season, can contain from 30 to 300 wt-% water based on fiber content. After cutting and drying the fiber can have a water content of from 20 to 30 wt-%. Because of the variation in water content of fiber source and the sensitivity of extrudate to water content, the control of water to a level of less than 8 wt-% in the pellet, based on pellet weight, is important.

When a structural member, such as the siding, or siding profile is extruded in a non-vented extrusion process, pellets should be as dry as possible and have a water content between 0.01 and 5 wt-%, or less than 3.5 wt-%. When using vented equipment in manufacturing the extruded linear member, a water content of less than 8 wt-% can be tolerated.

The pellets or linear extrudate are made by extrusion of the resin and fiber composite through an extrusion die resulting in a linear extrudate that can be cut into a pellet shape. The pellet cross-section can be any arbitrary shape depending on the extrusion die geometry. However, a regular geometric cross-sectional shape can be useful. Such regular cross-sectional shapes include a triangle, a square, a rectangle, a hexagonal, an oval, a circle, etc. The preferred shape of the pellet is a regular cylinder having a roughly circular or somewhat oval cross-section. The pellet volume is preferably greater than about 12 mm^3. The preferred pellet is a right circular cylinder, the preferred radius of the cylinder is at least 1.5 mm with a length of at least 1 mm. Preferably, the pellet has a radius of 1 to 5 mm and a length of 1 to 10 mm. Most preferably, the cylinder has a radius of 2.3 to 2.6 mm, a length of 2.4 to 4.7 mm, a volume of 40 to 100 mm^3, a weight of 40 to 130 mg and a bulk density of about 0.2 to 0.8 gm/mm^3.

The interaction, on a microscopic level, between the resin, polymer mass and the fiber is an important element. The physical properties of an extruded member are improved when the polymer melt, during extrusion of the pellet or linear member, thoroughly wets and penetrates the wood fiber particles. The thermoplastic material includes an exterior continuous organic polymer phase with the biofiber particle dispersed as a discontinuous phase in the continuous polymer phase. The material during mixing and extrusion obtains an aspect ratio of at least 1.1 or between 2 and 10, optimizes orientation such as at least 20 wt-% or 30% of the fibers are oriented in an extruder direction, and are thoroughly mixed and wetted by the polymer such that the exterior surfaces of the wood fiber are in contact with the polymer material. This means, that pores, crevices, cracks, passageways, indentations, etc., are filled by thermoplastic material. Such penetration is attained by ensuring that the viscosity of the polymer melt is reduced by operating at elevated temperature and using sufficient pressure to force the polymer into accessible internal pores, cracks and crevices within the biofiber in addition to filling like features on the biofiber surface.

During the pellet or linear extrudate manufacture, substantial work is done in providing a uniform dispersion of the fiber into the fluidized polymer. Such work produces a substantial number of orientable, acicular fiber particles. Such

particles are easily oriented into the extrusion direction by the flow field of the extrusion process resulting in extrusion of parts having improved structural properties.

The pellet dimensions are selected for both convenience in manufacturing and in optimizing the final properties the extruded materials. A pellet is with dimensions substantially less than the dimensions set forth above difficult to extrude, pelletize and handle in storage. Pellets larger than the range recited are difficult to introduce into extrusion or injection molding equipment, and are difficult to melt and form into a finished structural member, such as siding, profile or siding profile.

Thermoplastic polymer-biofiber composite material used to produce the siding profile is made under high shear conditions that are conducive to achieving intimate contact between polymer and fiber that result in the unique physical and mechanical properties exhibited in structural parts made from the composite. Appropriate high shear conditions can be produced in a variety of powder blenders and mixers. For example Nishibori uses a blade mixer (U.S. Patent No. 5,725,939) in tandem with an extruder to produce biofiber composite sheet materials. Screw mixers, especially extruders, are preferred processors ideally suited for cascading continuous chemical process unit operations such as heating, mixing, and devolatizing for example. Because small, controlled volumes of material sequentially pass through isolated zones along the screw(s), process parameters can be continuously monitored and adjusted using microprocessors. Therefore, a preferred process is the Krupp Werner & Pfleiderer (W & P) *KombiPlast* process wherein a co-rotating, twin screw extruder is used to make composite that is delivered to a single screw extruder operating in tandem where composite is further heated and compressed prior to delivery to an extrusion die. The die can be either a profile die for direct extrusion of the inventive siding unit, siding profile or pellet die.

The process steps used to make the thermoplastic-biofiber composite in a screw mixer generally begin with a fiber drying step wherein biofiber is conductively heated under mild shear conditions and the steam generated is vented from the mixer. Temperature, heat transfer, and shear are closely controlled to

optimize moisture vaporization to avoid fiber scorching, breaking, and geysering at the vent (at high moisture levels the steam generated blows fiber out the vent in geyser like fashion). If it is necessary to cushion the fiber during drying part or the entire thermoplastic can be added with the fiber during the drying step. Fiber moisture is preferably reduced to between 3 and 5 wt % during drying. Thermoplastic and optional regrind material is added to dried fiber at pre-selected point down the screw.

A "stuffer" screw may be used to add the thermoplastic depending on the pressure in the barrel at the addition point, which is related to the material throughput rate and compression. The proto-composite is mixed and heated to distribute thermoplastic throughout the fiber stream. Further downstream kneading blocks shear and mixes the composite. At this point, the thermoplastic melts (polyolefins) or fluxes (PVC) to form a fluid mass capable of forming a melt seal in the extruder. The temperature at this point can be 195 –215 degrees C for PVC composites. The fluid composite then passes through a high free volume vacuum devolatization zone operating at a vacuum of sufficient strength to remove volatile products from the composite but of insufficient strength to pull the composite apart (for example, a negative pressure of from 50 to 90 kilopascals). During devolatization the compressed composite abruptly expands and cools by as much as 10°C such that any thermal decomposition initiated during high shear mixing is quenched. Expanding volatile products vented through a vacuum port include, for example, steam, terpenes, lubricants, stabilizers, and small amounts of hydrogen chloride (when PVC comprises the thermoplastic). The expanded composite is recompressed to further intimate contact between fiber and thermoplastic before it is discharged into an evacuated transition box between the twin and single screw extruders. Upon entering the transition box, the composite now free of the confines of the extruder screw(s) is free to expand and cool in three dimensions. This expansion is sufficiently violent that some of the remaining, unruptured biofiber cells that have become steam filled during processing explode thus opening their interior volumes for subsequent introduction of fluxed polymer. Newly formed volatile products are evacuated at negative pressure in the range of from 50 to 95 kilopascals. Upon entering the single screw extruder, the composite is compressed

and heated to a pressure and temperature dictated by operating requirements of the extrusion die. Optional materials can be added to the composite at pre-selected points along the single screw.

When the composite is directly extruded through a profile die to form the inventive siding siding profile, the die may be optionally adapted to co-extrude capstock(s) on predetermined areas of the extruded profile external surface. Such capstocks include, but are not limited to, colored materials that enhance weatherability, abrasion resistant coatings, and the like.

Thermoplastic polymer-biofiber composite material is visco-elastic. Upon exiting the die, the hot extruded part is more a viscous fluid than an elastic solid. Post extrusion cooling and shaping process are applied to the part as it transforms to become more an elastic solid than a viscous fluid as it cools to ambient temperature. Therefore, the temperature, draw down, and cooling rate of the extruded part are controlled to minimize the residual stress in the finished part. Such "frozen in" stresses gradually relax over time at different rates that depend on the temperature of the end use environment. This stress relaxation can cause a retinue of mechanical problems for structures constructed from the extrude parts (profiles). Post extrusion cooling and shaping (calibrating) processes and apparatus are described by Purstinger, U.S. Patent No. 5,514,325; DeCoursey et al., U.S. Patent No. 5,008,051; and Groeblacher, U.S. Patents Nos. 5,578,328 & 5,484,577 the disclosures of which are hereby incorporated by reference.

When the composite is extruded through a stranding die to form pellets, the pressure, temperature, and cutter rotation speed are adjusted to optimize pellet uniformity and density. Pelletizing the composite permits decoupling of the composite making and extrusion processes. Pellets can be extruded as described above for the single screw portion of the W&P *KombiPlast* process, but pellets are preferably extruded using counter-rotating, twin screw extruders like the Cincinnati-Milicron CM-80, for example, that develop high die head pressures at low screw rotation speeds. Composite foaming, capstock co-extrusion, and down stream profile cooling and calibration processes are identical to those for direct profile extrusion described above.

In a variation of the process disclosed above, biofiber can be dried, thermoplastic can be melted or fluxed, and the fiber and plastic then mixed together in separate extruders. Such multi-extruder processes permit more precise control of the heat transfer during heating and the shear during mixing. Such an approach reduces the stress and comminution of acicular fiber particles that degrades the particle size distribution of the fiber and mechanical properties of structures made from the composite.

The high throughput process used to make thermoplastic-biofiber composite operate at a rate of at mass flow rates in the range of from 10 to 5000 kg-hr^{-1} and are capable of efficiently converting the maximum available mechanical energy supplied by blade and/or screw mixers into composite. However, the densification process further requires delivery of this energy at a rate sufficient to overcome the energy barriers opposing densification. Therefore the energy delivery of the process occurs at a shear rate and for a time sufficient to force thermoplastic into the biofiber cell interior without breaking acicular fibers (or otherwise commuting/ degrading the biofiber size distribution). The desired composite morphology is one where the fibers are surrounded and filled with thermoplastic to form a dense void free material as opposed a porous, unfilled structure of collapsed fibers that is to be avoided.

During extrusion of fluid composite through a profile die, the torque exerted on acicular fibers by shear gradients tend to rotate them in the flow direction thus producing a more aligned morphology that generally improves the mechanical properties of the resulting profile, the torque can easily exceed that required to break the fiber. Therefore, when the input fiber is highly acicular the shear rate, and/or the time spent by the material, in high shear parts of the process are minimized to prevent excessive particle breakage.

The versatility of W & P co-rotating, fully intermeshing twin screw extruders used in the *KombiPlast* process is described in greater detail by Marten et al. in U.S. Patent No. 5,051,222. The screw is designed in a segmented fashion so that a variety of different screw elements can be placed on keyed shafts to achieve the desired degree of mixing for a particular application. Screw elements can vary along the length of the screw, but the two screws must be matched to achieve fully

intermeshing surfaces. Generally speaking there are two different types of elements, screw conveying elements and kneading or mixing disks. The screw elements can have either a forward or reverse pitch, while the kneading disks can have a neutral pitch in addition to the forward or reverse pitch. The kneading disks consist of staggered elliptical disks that are offset to achieve an overall conveying pitch. The disks can vary in width from one element to another but are typically of uniform width within an element. In addition to a varied pitch in the kneading blocks, different screw elements can have different conveying pitches.

As can be expected, all of the elements impart different levels of shear history and conveying ability. These can be summarized in the following list of elements and their relative shear intensity:

Greatest Shear--Least Forward Conveying Efficiency
- reverse pitch screw elements
- reverse pitch kneading blocks
- neutral kneading blocks
- forward pitch kneading blocks
- forward pitch screw elements

Least Shear--Most Forward Conveying Efficiency

In addition, wider kneading blocks impart more shear to the melt. Also tighter pitch imparts more shear. A worker skilled in the art can combine all of these factors to design a screw that achieves the required balance between shear input and conveying efficiency as material moves along the screw without thermally or mechanically degrading the composite material as it forms.

In co-rotating twin-screw extruders the shear rate and residence time spent by extrudate in the high shear (generally the kneading) zones of the extruder is a complex interactive function of screw rotation speed (RPM) and extruder screw/barrel geometry. However, the following general observations are relevant:

For a given geometry the shear rate increases in direct proportion to screw speed and narrowing of the clearance between the tips of various screw elements and the extruder barrel (affected by the degree of wear);

The residence time spent by the extrudate in the high shear zone is determined by the degree of fill of the extruder screw and the following interactive geometrical factors: 1) the width of the narrow clearance zone (the number and width of kneading block elements used in the screw design), 2.) the number of lobes

on the screw elements--(increasing number of lobes increases the volume of material in the narrow clearance zone while simultaneously reducing the free volume of lower shear zone between the tip and root of the screw element); and 3.) the number and type of reverse (left-handed) elements included in the screw design). Suitable extruders useful for making thermoplastic polymer-biofiber composite material are available from Krupp Werner Pfleiderer, Leistritz, Davis Standard, and Entek Manufacturing, Inc.

The thermoplastic-biofiber composite siding profile can be manufactured with an additional surface layer, protective coating, capstock layer on any surface, or portion thereof on the exterior or interior of the siding profile. The coating, layer, or capstock can provide environmental stability, wear resistance, resistance to environmental moisture, stability to ultraviolet light or any other physical or chemical property that can tend to improve the wear ability or lifetime of any aspect of the siding profile. Extruded capstock materials are known for use in the formation of extruded profile materials. Coextruding a layer of an acrylic, a chloropolymer, a fluoropolymer, or other blended polymeric material that can maintain the surface quality of the profile typically makes an effective protective layer. A representative abrasion resistant coating is LUCITE® TufCoat 4600, available from ICI Acrylics, Memphis, TN. Capstocks can have a clear, colored or patterned appearance. The colors can be formed by the addition of dyes and/or pigments to the capstock layer to form a green, Terratone, white, or other colored appearance. Further, the capstock can take the appearance of a wood grain, a stone-like appearance or other natural surface quality. Such capstock layers are manufactured by coating, painting or coextruding the thermoplastic material in a thin layer onto the siding profile during the extrusion of the siding profile. During extrusion, the capstock layer is carefully gauged in thickness to conserve material but to provide an excellent surface and acceptable appearance (less than two millimeters, or less than 1 millimeter). Typical properties of a thermoplastic-biofiber composite materials formed from compositions comprising approximately 60 wt. % PVC, 40 wt % wood fiber (PVC) and 30 wt % polypropylene, 70 wt. % wood fiber (PP) are shown in Table -1 Example 1.

2-Part Siding Unit Manufacture

The 2-part siding unit is formed by securing the siding profile to upper flange. As described above, the siding profile and the upper flange can be formed separately by extrusion. The siding profile can be formed before or after the upper flange is formed. If the upper flange is formed before the siding profile, the upper flange can be secured to the siding profile as the siding profile is being manufactured.

The 2-part siding unit can be manufactured with tight tolerances. The upper flange and siding profile can be aligned to maintain an overall manufacturing tolerance that is less than the manufacturing tolerance of the upper flange added to the manufacturing tolerance of the siding profile. This is due to the overlapping of the upper flange and siding profile. Thus, the formation of the upper flange and siding profile can be preformed under easier tolerances. The easier tolerances allow the upper flange and main body to be manufactred quickly and economically. A subsequent alignment step maintains the tight overall manufacturing tolerances necessary for manufacturing a consistent siding product.

After the upper flange and siding profile are aligned, the upper flange and siding profile are secured together. The upper flange and siding profile can be secured with, for example, an adhesive, thermal or ultrasonic welding. Energy directors may be used to aid in the fastening as described above.

After the upper flange and siding profile are secured together forming the 2-part siding unit, the 2-part siding unit is cut to a desired length. The 2-part siding unit can be cut to lengths that are longer than the 12 foot lengths vinyl siding is cut to. The 2-part siding can be cut to lengths of 5 meters (16 feet) or greater. The whole manufacturing process or portion thereof can be portable and operated at the installation site to provide 2-part siding lengths that are cut to exact lengths needed for the particular installation.

2-Part Siding Mechanical Properties

The Young's modulus of the siding profile in the extrusion direction can be at least 500,000 psi, 800,000 psi or 1,000,000 psi as measured by ASTM D3039. The Flexural Modulus of the siding profile can be at least 500,000 psi as measured by ASTM D790.

The Young's modulus of the upper flange profile in the extrusion direction should be about at least 100,000 psi, 300,000 psi or 500,000 as measured by ASTM D3039. The Flexural Modulus of the upper flange can be at least 400,000 psi as measured by ASTM D790.

2-Part Siding Thermal Properties

The Coefficient of Thermal Expansion (COTE) of the thermoplastic polymer-biofiber composite materials can range from 4.5 x 10^{-5} m/m/°C (2.5 x 10^{-5} in/in/°F) to 3 x 10^{-5} m/m/°C (1 x 10^{-5} in/in/°F) and all numerical values subsumed therein. The Heat Deflection Temperature is the temperature at which a standard test bar deflects a specified amount under a stated load. The PVC containing composite used in the invention has a Heat Deflection Temperature of 78 degrees Celsius at 1.82 megapascals and a Heat Deflection Temperature of 105 degrees Celsius at 0.46 megapascals as measured by ASTM D648. The flash ignition temperature is the minimum temperature at which sufficient flammable gas is emitted to ignite momentarily upon application of a small external pilot flame. The Flash Ignition Temperature of the PVC composite is 410 degrees Celsius as measured by ASTM D1929. The Self-Ignition Temperature is the minimum temperature at which the specimen spontaneously ignites in the absence of a flame ignition source. The Self-Ignition Temperature of the PVC composite is 425 degrees Celsius as measured by ASTM D1929. The Flame Spread Index is the a number or classification indicating a comparative measure of surface burning behavior derived from observations made during the progress of the boundary of a zone of flame under defined test conditions. The Flame Spread Index of the PVC composite is 10 as measured by ASTM E84. The Average Flame Spread Index is a number indicating a comparative measure of surface flammability of materials using a radiant heat source under defined test conditions. The Average Flame Spread Index of the PVC composite is 22.7 as measured by ASTM E162.

Installation of the Siding System

The siding system of the invention can be assembled with a variety of known mechanical fastener techniques. Such techniques include staples, screws, nails, and other hardware.

The low coefficient of thermal expansion and structural strength of the thermoplastic polymer-biofiber composites, when coupled with partitioning of potential buckleing inducing length changes obtained be fixedly attaching the siding panel to the substrate, permits use very long length planks. The 2-part siding unit may be "hard nailed" in the center of the 2-part siding unit length. This allows for expansion and contraction to occur in both horizontal directions from the center of the 2-part siding unit. The remaining fasteners may be "loose nailed" allowing horizontal movement along the 2-part siding unit.

The 2-part siding units can be made a fixed length shorter than the width of a side of most houses, and thus it is necessary to butt, splice or join two 2-part siding units together at their ends. Each 2-part siding unit may have a nominal length of 16 feet, with an actual length of 16 feet, 4 inches. With respect to the vertical siding designs, the length may be 12 feet. Adjacent 2-part siding units are connected end-to-end with a butt joint, and there is no overlapping of the siding units with this type of connection. The ends of each siding unit may be mitered to have a beveled interconnection surface. Components of the system can also be joined by use of: glue, or a melt fusing technique wherein a fused weld forms a joint between two 2-part siding units, or the 2-part siding units can be joined by splines adapted to fit with the interior structure of the siding unit. Such joints can be bonded using a spline placed into the profile that is hidden when joinery is complete. Such a spline can be adhesively attached, thermally welded, heat staked into place or mechanically fastened. The butt-joint may also be formed by frictional engagement or mechanical interlock. The spline can be injection molded or formed from similar thermoplastics and can have a service adapted for compression fitting and secure attachment to the structural member of the invention. Such a spline can project from 1 to 12 inches into the interior of the siding unit.

Further, components of the siding system can be assembled by gluing components together with a solvent, structural or hot melt adhesive. Solvent borne adhesives that can act to dissolve or soften thermoplastic present in the components and to promote solvent based adhesion or welding of the materials. In the welding technique, once the joint surfaces are formed, the surfaces of the joint can be heated to a temperature above the melting point of the composite material and while hot,

the mating surfaces can be contacted in a configuration required in the assembled structure. The contacted heated surfaces fuse through an intimate mixing of molten thermoplastic from each surface. Once mixed, the materials cool to form a structural joint having strength typically greater than joinery made with conventional techniques. Any excess thermoplastic melt that is forced from the joint area by pressure in assembling the surfaces can be removed using a heated surface, mechanical routing, or a precision knife cutter.

Using these general assembly techniques, the siding system of the invention is typically constructed by installing siding units on a support surface. Such support surfaces can often comprise a concrete surface, wood framing, I-beam joist framing, plywood on a frame support or any other suitable contact surface. The siding unit is often cut to appropriate length and laid on the surface.

EXAMPLES

Example 1

Table 1 below show various physical properties of two thermoplastic-biofiber composite material siding profiles. The first composite is a PVC-biofiber composite that contains 60 wt.% polyvinyl chloride (PVC) and 40 wt.% wood fiber made by the extrusion process detailed above. The second composite is a PP-biofiber composite that contains 30 wt.% polypropylene (PP) and 70 wt.% wood fiber made by the extrusion process detailed above.

Table 1. Thermoplastic-Biofiber Composites

Measurement	ASTM Method	Units	PVC-Biofiber Composite	PP-Biofiber Composite
Tensile Modulus	D3039	psi(MPa)	950,000 (6,500)	850,000 (5,585)
Tensile Strenght	D3039	psi(MPa)	5,500 (38)	5,750 (40)
Tensile % Strain	D3039	%	1	4
Flexural	D790	psi(MPa)	830,000 (5,700)	657,000 (4,530)

Measurement	ASTM Method	Units	PVC-Biofiber Composite	PP-Biofiber Composite
Modulus				
Modulus of Rupture	D790	psi(MPa)	10,000 (69)	10,000 (69)
Izod Notched Impact	D256	in-lb/in (J/m)	7 (370)	16 (846)
Specific Gravity	D792	g/cm^3	1.4	1.23
HDT (264 psi)	D648	°F(°C)	173 (78)	306 (152)
COTE	D696	in/in/°F	1.6×10^{-5}	1.3×10^{-5}

Example 2

Table 2 below shows various physical properties of materials that can be used to form the siding profile. Lengths of the siding were manufactured and tested for coefficient of thermal expansion, thermal conductivity, decay, corrosion, heat distortion temperature, water absorption, moisture expansion, and compression load. For many of these characteristics, the composite siding of the present invention was compared to siding manufactured with conventional siding materials. Table 2 displays the test data developed in these experiments and obtained from published sources. The material of the preferred siding unit is indicated by the designation "Biofiber-Thermoplastic" in the Examples below. This "Biofiber-Thermoplastic" composite material is the material described above, made of 60 wt-% polyvinyl chloride and 40 wt-% fiber derived from a soft wood.

Using the methods for manufacturing a pellet and extruding the pellet, a siding member as illustrated in Figures 6A-D was manufactured using an appropriate extruder die. The melt temperature of the input to the machine was 390°-420°F. A vacuum was pulled on the melt mass of no less that 3 inches mercury. The overall width of the siding profile was 6 inches. The wall thickness of any of the elements of the extrudate was about 0.1 inch.

Several different siding materials were tested and/or analyzed, as shown in the tables below. The data for the five types of siding materials, other than the composite material, was obtained from published sources. For aluminum, the data was obtained from *Metals Handbook*, Vol. 2, 9th Ed., American Society for Metals, 1990. For PVC, the data was obtained from the specifications and product literature for PVC siding which is manufactured by Reynolds Metals Company of Richmond, Virginia. For cedar, the data was obtained from *Forest Products and Wood Science*, J.G. Haygreen and J.L. Bowyer, The Iowa State University Press, 1982. For Masonite™, the data was obtained from the specifications and product literature for Masonite siding obtained from Masonite Corporation of Chicago, Illinois. (The Masonite material is a fiber board material made from hard wood fibers and cement binders.) The data for steel was obtained from *Metals Handbook*, Vol. 1, 9th Ed., American Society for Metals, 1990.

The determination of the dent resistance of impact of the siding profiles by a falling mass was determined by the following procedure. This procedure is a modification of the CEN/TC33 "European Standard Method for the determination of the resistance to impact by a falling mass at about 21.1°C (70°F) of unplasticized polyvinyl chloride (PVC-U) siding profiles used in the fabrication of windows and doors for the assessment of physical properties of the extrusion piece. Eighteen inch length test pieces (about 48.5 centimeters) were cut from lengths of siding profiles and were subjected to a blow from a mass falling from a known height on the surface of the profile at a point midway between two supporting webs at a fixed width and at a fixed temperature. After testing, the profiles are visually examined for failures which appear at the point of impact. Siding profile typically refers to an extruded piece having load bearing functions in a construction such as a window or door. The test surface, sight surface or face surface of the profile is a surface exposed to view when the window is closed. The falling weight impacts the face surface, sight surface or exposed surface. A web typically refers to a membrane which can be rigid or non-rigid connecting two walls of the siding profile. The impact testing machine apparatus incorporates the following basic components. The main frame is rigidly fixed in a vertical position. Guide rails fixed to the main frame accommodate the falling mass and allow it to fall freely in the vertical plane directly

impacting the face surface or the sight surface of the test profile. The test piece support consists of a rounded off support member with a distance between 200 ± 1 millimeters. The support is made from steel and rigidly fixed in a solid foundation or on a table with a mass of more than 50 kilograms for stability. A release mechanism is installed such that the falling mass can fall through a height which can be adjusted between 1500 ± 10 millimeters measured from a top surface of the test piece to the bottom surface of the falling mass. The falling mass is selected having 1000 ± 5 grams. The falling mass has a hemispherical striking surface that contacts the face surface of the profile. The hemispherical striking surface has a radius of about 25 ± 0.5 millimeters. The striking surface of the falling mass shall be smooth and conform to the hemispherical striking shape without the imperfections that could cause damage resulting from effects other than impact. One or more test pieces were made by sawing appropriate lengths from typical production profile extrusion pieces. The test pieces were conditioned at a temperature of about 21.1 ± 0.2°C for at least one hour prior to testing. Each test piece was tested within 10 seconds of removal from the conditioning chamber to ensure that the temperature of the piece did not change substantially. The profile was exposed to the impact from the falling mass onto the sight surface, face surface or exposed surface of the profile. Such a surface is the surface designed to be exposed to the weather. The falling mass is dropped directly onto the sight surface at a point midway between the supporting webs. The profile is to be adjusted with respect to the falling mass such that the falling mass strikes in a direction normal to the surface of the test face. The results of the testing are shown by tabulating the number of test pieces tested, the number of pieces broken or if not broken, the depth of any defect produced in the profile by the test mass.

Table 2. Siding Material

Material	COTE in/in/F° x10⁻⁶	Thermal Conductivity W/mK	Decay	Corrosion	HDT	Water Absorption	Standards	Ref.	Dent Resistance Testing*
Biofiber-Thermoplastic	10 to 20	0.17	N/A	N/A	200°F	0.90%	Yes	1	-0.0070
Aluminum	12.1	173	N/A	Yes	N/A	N/A	Yes	2	**
PVC	36	0.11	N/A	N/A	170°F	N/A	Yes	3	-0.0650
Cedar	3 to 5	0.09	Yes	N/A	N/A	Yes	Yes	4	-0.0630
Masonite	N/A	N/A	Yes	N/A	N/A	12%	Yes	5	-0.0025
Steel	12	59.5	N/A	Yes	N/A	N/A	Yes	6	-0.0315

* Values obtained from testing performed at Aspen Research Corporation
** Value for interval could not be measured due to surface deformation
1. Fibrex Design Manual and Aspen Research Corp. test reports
2. Metals Handbook Vol. 29th Edition.
3. Specifications for Reynolds Siding - values obtained from product literature
4. Forest Products and Wood Science, JG Haygreen and JL Boyer, 1982 The Iowa State University Press
5. Masonite product literature
6. Metals Handbook Vol. 19th Edition.

Explanation of N/A status:
Decay: The N/A status indicates the material is not subject to decay because there is no biological mechanism to indicate decay
Corrosion: The N/A status indicates no mechanism in the material to promote corrosion
HDT (heat distortion temperature): The metals do not distort until an extremely high temperature which is outside the range of what siding would experience; therefore, not applicable. The N/A values for Masonite indicate that the value was not available.
Water Absorption: The metals do not take up water; hence, the N/A status. The PVC value is low enough to be considered to be negligible.
ASTM Test Methods
COTE D696 - for Composite and PVC
Thermal Conductivity F433 - for Composite and PVC
HDT (heat distortion temperature) D648 for Composite and PVC
Moisture Absorption D570-84 for Composite and PVC

Example 3

Table 3 shows the failure energy for various invention embodiments. Each embodiment was tested as installed on a building substrate. The embodiments were tested by striking the siding profile at the point most susceptible to impact failure. All 2-part siding units had a PVC upper flange.

The PVC-biofiber siding profile contained 60 wt.% PVC and 40 wt.% wood fiber formed by the process discussed above.

Table 3. 2-Part siding unit Failure Energy

Embodiment (Refer to Figures)	Warm 65°F (in-lbs)	Cold 15°F (in-lbs)
Figure 6A-C PVC-biofiber (Hollow)	3	3
Figure 1A-C PVC-biofiber	56	51

The failure energy measurements were made in accord with ASTM D5420 (Gardner Impact). An instrumented impacter (equipped with an accelerometer) having a mass of 2 pounds and a contact diameter of 2.2 inches was used in this modified Gardner Impact Test.

The various embodiments described above are provided by way of illustration only and should not be construed to limit the invention. Those skilled in the art to which the invention most closely pertains will readily recognize various modifications and changes that may be made to the present invention without strictly following the exemplary embodiments and applications illustrated and described herein, and without departing from the true scope of the present invention that is set forth in the following claims.

WE CLAIM:

1. A siding unit, comprising:
   (a) a siding profile made of a thermoplastic-biofiber composite material; and
   (b) an upper flange fastened to the siding profile where the upper flange is made of a thermoplastic polymer.

2. The siding unit of claim 1, wherein the siding profile comprises 50 to 90 parts of biofiber and 10 to 50 parts of polymer per 100 parts of thermoplastic-biofiber composite material.

3. The siding unit of claim 1, wherein the upper flange comprises polyvinyl chloride.

4. The siding unit of claim 1, wherein the siding profile has a coefficient of thermal expansion less than a coefficient of thermal expansion of the upper flange.

5. The siding unit of claim 4, wherein the upper flange coefficient of thermal expansion is at least 1.5 times the siding profile coefficient of thermal expansion.

6. The siding unit of claim 4, wherein the upper flange coefficient of thermal expansion is at least 2 times the siding profile coefficient of thermal expansion.

7. The siding unit of claim 4, wherein the siding profile coefficient of thermal .expansion is less than 4.5×10^{-5} m/m/°C (2.5×10^{-5} in/in/°F).

8. The siding unit of claim 4, wherein the upper flange coefficient of thermal expansion is more than 4.5×10^{-5} m/m/°C (2.5×10^{-5} in/in/°F).

9. The siding unit of claim 7, wherein the siding profile coefficient of thermal expansion is 3×10^{-5} m/m/°C (1×10^{-5} in/in/°F).

10. The siding unit of claim 8, wherein the upper flange coefficient of thermal expansion is 6×10^{-5} m/m/°C (3.4×10^{-5} in/in/°F).

11. The siding unit of claim 1, wherein at least a portion of the upper flange is overlapping the siding profile.

12. The siding unit of claim 11, wherein the upper flange is fastened to the siding profile by an ultrasonic or thermal weld.

13. The siding unit of claim 1, further including means for supporting the siding profile or a second siding profile substantially parallel to the siding profile and overlapping the upper flange.

14. The siding unit of claim 13, wherein the means for supporting the siding profile includes a projection on an inner surface of the siding profile.

15. The siding unit of claim 14, wherein the projection is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

16. The siding unit of claim 14, wherein the projection is made of a porous thermoplastic-biofiber composite material.

17. The siding unit of claim 13, wherein the means for supporting the second siding profile substantially parallel to the siding profile and overlapping the upper flange includes a fin integral with the upper flange and distal to the siding profile.

18. The siding unit of claim 13, wherein the means for supporting the second siding profile substantially parallel to the siding profile and overlapping the upper flange includes an arch integral with the upper flange and distal to the siding profile.

19. The siding unit of claim 17, wherein the fin is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

20. The siding unit of claim 18, wherein the arch is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

21. The siding unit of claim 1, wherein the siding profile includes an inner surface and an outer surface defining a cavity.

22. The siding unit of claim 21, wherein at least a portion of the cavity comprises a porous thermoplastic-biofiber composite material or a foam.

23. The siding unit of claim 1, wherein the siding profile is a solid member.

24. The siding unit of claim 22, wherein the siding profile has a thickness of 2.5 mm (0.10 in) to 3.8 mm (0.15 in).

25. The siding unit of claim 23, wherein the siding profile has a thickness of 3.2 mm (0.12 in).

26. The siding unit of claim 1, wherein the siding profile includes a layer of capstock over at least a portion of the siding profile.

27. The siding unit of claim 1, wherein the upper flange includes a plurality of elongated slots in an offset vertical relation.

28. The siding unit of claim 1, wherein the siding profile is a single-face profile.

29. The siding unit of claim 1, wherein the siding profile is a double-face profile.

30. The siding unit of claim 1, wherein an outer surface of the siding profile is convex.

31. The siding unit of claim 1, wherein an outer surface of the siding profile is planar.

32. A siding assembly for attachment to a building substrate, comprising:

(a) a plurality of siding units, each siding unit having:

(i) a siding profile made of a thermoplastic-biofiber composite material;

(ii) an upper flange fastened to the siding profile where the upper flange is made of a thermoplastic polymer; and

(b) a plurality of fasteners to fasten the siding units to a building substrate.

33. The siding assembly of claim 32, further including a building interface trim unit.

34. The siding assembly of claim 33, wherein the building interface trim unit is made of a thermoplastic-biofiber composite material.

35. The siding assembly of claim 34, wherein the building interface trim unit includes:

(a) an inner surface;

(b) an outer surface;

(c) a first side edge; and

(d) a second side edge parallel to the first side edge and having a serrated profile mating with an outer surface of the siding profile.

36. The siding assembly of claim 32, further including means for butt-joining adjacent siding units.

37. The siding assembly of claim 36, wherein the means for joining adjacent siding units includes a spline sized and configured to fit against an inner surface of the siding profile.

38. The siding assembly of claim 37, wherein the spline is made of a thermoplastic polymer.

39. The siding assembly of claim 38, wherein the spline includes at least one ridge extending along at least a portion of a length of the spline.

40. The siding assembly of claim 39, wherein the spline includes a plurality of ridges vertically spaced and extending along at least a portion of a length of the spline.

41. The siding assembly of claim 32, further including a building substrate.

42. A siding unit formed by the process of fastening a thermoplastic-biofiber composite siding profile to a thermoplastic polymeric upper flange.

43. The siding unit formed by the process of claim 42, wherein the siding profile comprises 50 to 90 parts of biofiber and 10 to 50 parts of polymer per 100 parts of thermoplastic-biofiber composite material.

44. The siding unit formed by the process of claim 42, wherein the upper flange comprises polyvinyl chloride.

45. The siding unit of claim 42, wherein the siding profile has a coefficient of thermal expansion less than a coefficient of thermal expansion of the upper flange.

46. The siding unit of claim 45, wherein the upper flange coefficient of thermal expansion is at least 1.5 times the siding profile coefficient of thermal expansion.

47. The siding unit of claim 45, wherein the upper flange coefficient of thermal expansion is at least 2 times the siding profile coefficient of thermal expansion.

48. The siding unit formed by the process of claim 45, wherein the siding profile coefficient of thermal expansion is less than 4.5 $\times 10^{-5}$ m/m/°C (2.5 $\times 10^{-5}$ in/in/°F).

49. The siding unit formed by the process of claim 45, wherein the upper flange coefficient of thermal expansion is more than 4.5 $\times 10^{-5}$ m/m/°C (2.5 $\times 10^{-5}$ in/in/°F).

50. The siding unit formed by the process of claim 48, wherein the siding profile coefficient of thermal expansion is 3 $\times 10^{-5}$ m/m/°C (1 $\times 10^{-5}$ in/in/°F).

51. The siding unit formed by the process of claim 49, wherein the upper flange coefficient of thermal expansion is 6 $\times 10^{-5}$ m/m/°C (3.4 $\times 10^{-5}$ in/in/°F).

52. The siding unit formed by the process of claim 42, wherein at least a portion of the upper flange is overlapping the siding profile.

53. The siding unit formed by the process of claim 52, wherein the upper flange is fastened to the siding profile by an ultrasonic or thermal weld.

54. The siding unit formed by the process of claim 42, further including means for supporting the siding profile or a second siding profile substantially parallel to the siding profile and overlapping the upper flange.

55. The siding unit formed by the process of claim 54, wherein the means for supporting the siding profile includes a projection on an inner surface of the siding profile.

56. The siding unit of formed by the process claim 55, wherein the projection is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

57. The siding unit formed by the process of claim 55, wherein the projection is made of a porous thermoplastic-biofiber composite material.

58. The siding unit formed by the process of claim 54, wherein the means for supporting the second siding profile substantially parallel to the siding profile and overlapping the upper flange includes a fin integral with the upper flange and distal to the siding profile.

59. The siding unit formed by the process of claim 54, wherein the means for supporting the second siding profile substantially parallel to the siding profile and overlapping the upper flange includes an arch integral with the upper flange and distal to the siding profile.

60. The siding unit formed by the process of claim 58, wherein the fin is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

61. The siding unit formed by the process of claim 59, wherein the arch is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

62. The siding unit formed by the process of claim 42, wherein the siding profile includes an inner surface and an outer surface defining a cavity.

63. The siding unit formed by the process of claim 62, wherein at least a portion of the cavity comprises a porous thermoplastic-biofiber composite material or a foam.

64. The siding unit formed by the process of claim 42, wherein the siding profile is a solid member.

65. The siding unit formed by the process of claim 64, wherein the siding profile has a thickness of 2.5 mm (0.10 in) to 3.8 mm (0.15 in).

66. The siding unit formed by the process of claim 64, wherein the siding profile has a thickness of 3.2 mm (0.12 in).

67. The siding unit formed by the process of claim 42, wherein the siding profile includes a layer of capstock over at least a portion of the siding profile.

68. The siding unit formed by the process of claim 42, wherein the upper flange includes a plurality of elongated slots in an offset vertical relation.

69. The siding unit formed by the process of claim 42, wherein the siding profile is a single-face profile.

70. The siding unit formed by the process of claim 42, wherein the siding profile is a double-face profile.

71. The siding unit formed by the process of claim 42, wherein an outer surface of the siding profile is convex.

72. The siding unit formed by the process of claim 42, wherein an outer surface of the siding profile is planar.

73. The siding unit formed by the process of claim 42, wherein the thermoplastic-biofiber composite siding profile is formed by extrusion.

74. The siding unit formed by the process of claim 42, wherein the thermoplastic polymeric upper flange is formed by extrusion.

75. A method of manufacturing a siding unit comprising:

(a) forming a siding profile;

(ii) forming an upper flange; and

(iii) fastening the siding profile to the upper flange.

76. The method of manufacturing a siding unit of claim 75, wherein the siding profile is made of a thermoplastic-biofiber composite and the upper flange is made of a thermoplastic polymer.

77. The method of manufacturing a siding unit of claim 75, wherein the siding profile comprises 50 to 90 parts of biofiber and 10 to 50 parts of polymer per 100 parts of thermoplastic-biofiber composite material.

78. The method of manufacturing a siding unit of claim 75, wherein the upper flange comprises polyvinyl chloride.

79. The siding unit of claim 75, wherein the siding profile has a coefficient of thermal expansion less than a coefficient of thermal expansion of the upper flange.

80. The siding unit of claim 79, wherein the upper flange coefficient of thermal expansion is at least 1.5 times the siding profile coefficient of thermal expansion.

81. The siding unit of claim 79, wherein the upper flange coefficient of thermal expansion is at least 2 times the siding profile coefficient of thermal expansion.

82. The method of manufacturing a siding unit of claim 79, wherein the siding profile coefficient of thermal expansion is less than 4.5 $\times 10^{-5}$ m/m/°C (2.5 x 10^{-5} in/in/°F).

83. The method of manufacturing a siding unit of claim 79, wherein the upper flange coefficient of thermal expansion is more than 4.5 $\times 10^{-5}$ m/m/°C (2.5 x 10^{-5} in/in/°F).

84. The method of manufacturing a siding unit of claim 82, wherein the siding profile coefficient of thermal expansion is 3 $\times 10^{-5}$ m/m/°C (1 x 10^{-5} in/in/°F).

85. The method of manufacturing a siding unit of claim 83, wherein the upper flange coefficient of thermal expansion is 6 $\times 10^{-5}$ m/m/°C (3.4 x 10^{-5} in/in/° F).

86. The method of manufacturing a siding unit of claim 75, wherein at least a portion of the upper flange is overlapping the siding profile.

87. The method of manufacturing a siding unit of claim 83, wherein the upper flange is fastened to the siding profile by an ultrasonic or thermal weld.

88. The method of manufacturing a siding unit of claim 75, further including means for supporting the siding profile or a second siding profile substantially parallel to the siding profile and overlapping the upper flange.

89. The method of manufacturing a siding unit of claim 88, wherein the means for supporting the siding profile includes a projection on an inner surface of the siding profile.

90. The method of manufacturing a siding unit of claim 89, wherein the projection is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

91. The method of manufacturing a siding unit of claim 89, wherein the projection is made of a porous thermoplastic-biofiber composite material.

92. The method of manufacturing a siding unit of claim 88, wherein the means for supporting the second siding profile substantially parallel to the siding profile and overlapping the upper flange includes a fin integral with the upper flange and distal to the siding profile.

93. The method of manufacturing a siding unit of claim 88, wherein the means for supporting the second siding profile substantially parallel to the siding profile and overlapping the upper flange includes an arch integral with the upper flange and distal to the siding profile.

94. The method of manufacturing a siding unit of claim 92, wherein the fin is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

95. The method of manufacturing a siding unit of claim 93, wherein the arch is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

96. The method of manufacturing a siding unit of claim 75, wherein the siding profile includes an inner surface and an outer surface defining a cavity.

97. The method of manufacturing a siding unit of claim 96, wherein at least a portion of the cavity comprises a porous thermoplastic-biofiber composite material or a foam.

98. The method of manufacturing a siding unit of claim 75, wherein the siding profile is a solid member.

99. The method of manufacturing a siding unit of claim 98, wherein the siding profile has a thickness of 2.5 mm (0.10 in) to 3.8 mm (0.15 in).

100. The method of manufacturing a siding unit of claim 98, wherein the siding profile has a thickness of 3.2 mm (0.12 in).

101. The method of manufacturing a siding unit of claim 75, wherein the siding profile includes a layer of capstock over at least a portion of the siding profile.

102. The method of manufacturing a siding unit of claim 75, wherein the upper flange includes a plurality of elongated slots in an offset vertical relation.

103. The method of manufacturing a siding unit of claim 75, wherein the siding profile is a single-face profile.

104. The method of manufacturing a siding unit of claim 75, wherein the siding profile is a double-face profile.

105. The method of manufacturing a siding unit of claim 75, wherein an outer surface of the siding profile is convex.

106. The method of manufacturing a siding unit of claim 75, wherein an outer surface of the siding profile is planar.

107. The method of manufacturing a siding unit of claim 75, wherein the thermoplastic-biofiber composite siding profile and thermoplastic polymeric upper flange are formed by extrusion.

108. The method of manufacturing a siding unit of claim 107, wherein the upper flange is fastened to the thermoplastic-biofiber composite siding profile during the extrusion of the thermoplastic-biofiber composite siding profile.

109. The method of manufacturing a siding unit of claim 107, wherein the thermoplastic-biofiber composite siding profile is fastened to the upper flange during the extrusion of the upper flange.

110. The method of manufacturing a siding unit of claim 107, wherein the thermoplastic-biofiber composite siding profile is fastened to the upper flange during the extrusion of the upper flange and thermoplastic-biofiber composite siding profile.

111. The method of manufacturing a siding unit of claim 107, further including aligning the upper flange and siding profile to maintain an overall manufacturing tolerance less than the manufacturing tolerance of the upper flange added to the manufacturing tolerance of the siding profile.

112. The method of manufacturing a siding unit of claim 75, further including cutting the siding unit to a desired length.

113. The method of manufacturing a siding unit of claim 112, wherein the length is 5 meters (16 feet) or greater.

114. A siding unit manufactured by the method of claim 75.

115. A method of installing siding, comprising:

(a) fastening a siding unit to a building substrate, each unit having:

(i) a siding profile made of a thermoplastic-biofiber composite material; and

(ii) an upper flange fastened to the siding profile where the upper flange is made of a thermoplastic polymer.

116. The method of installing siding of claim 115, further including fastening a building interface trim unit to the building substrate at a building interface.

117. The method of installing siding of claim 116, wherein the building interface trim unit is made of a thermoplastic-biofiber composite material.

118. The method of installing siding of claim 117, wherein the building interface trim unit includes:

(a) an inner surface;

(b) an outer surface;

(c) a first side edge; and

(d) a second side edge parallel to the first side edge and having a serrated profile mating with an outer surface of the siding profile.

119. The method of installing siding of claim 115, further including butt-joining adjacent siding units with means for butt-joining adjacent siding units.

120. The method of installing siding of claim 119, wherein the butt joining adjacent siding units with means for joining adjacent siding units includes fastening a spline sized and configured to fit against an inner surface of the siding profile to an inner surface of a first siding profile and an inner surface of a second adjacent siding profile.

121. The method of installing siding of claim 120, wherein the spline is made of a thermoplastic polymer.

122. The method of installing siding of claim 121, wherein the spline includes at least one ridge extending along at least a portion of a length of the spline.

123. The method of installing siding of claim 122, wherein the spline includes a plurality of ridges vertically spaced and extending along at least a portion of a length of the spline.

124. The method of installing siding of claim 115, further including engaging a second siding unit siding profile with the upper flange of the fastened siding unit.

125. The method of installing siding of claim 124, further including aligning the second siding unit siding profile with the fastened siding unit siding profile.

126. The method of installing siding of claim 125, further including fastening the aligned second siding unit to the building substrate.

127. The method of installing siding of claim 115, wherein the fastening includes hard nailing the siding unit to the building substrate.

128. The method of installing siding of claim 115, wherein the fastening includes loose nailing the siding unit to the building substrate.

129. A building interface trim unit, comprising:
  (a) a elongated body having:
    (i) an inner face;
    (ii) an outer face;
    (iii) a first side edge and;
    (iv) a second side edge parallel to the first side edge and having a serrated profile.

130. The building interface trim unit of claim 129, wherein the building interface trim unit is made of a thermoplastic-biofiber composite material.

131. The building interface trim unit of claim 129, wherein the building interface trim unit comprises 50 to 90 parts of biofiber and 10 to 50 parts of polymer per 100 parts of thermoplastic-biofiber composite material.

FIG. 1A

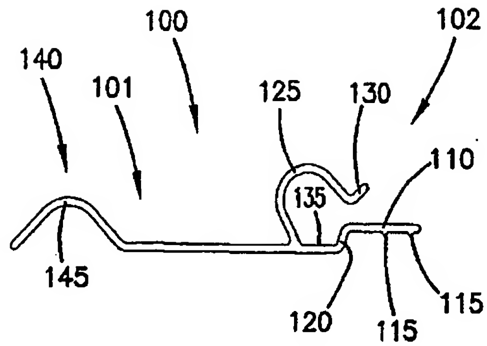
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FIG. 1B

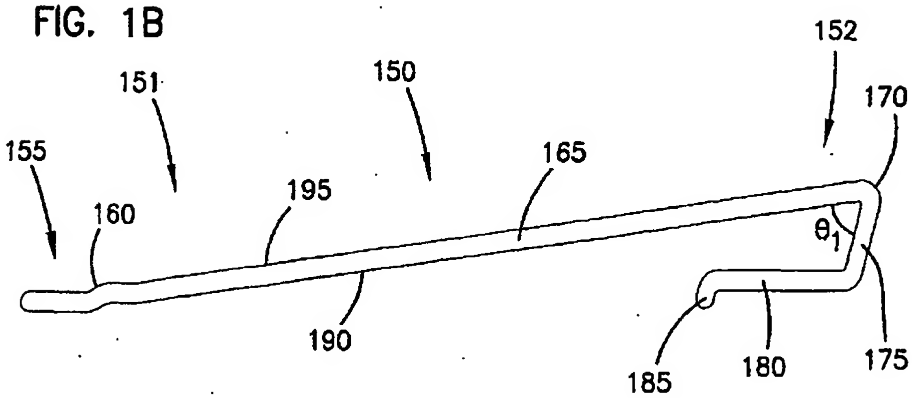
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FIG. 1C

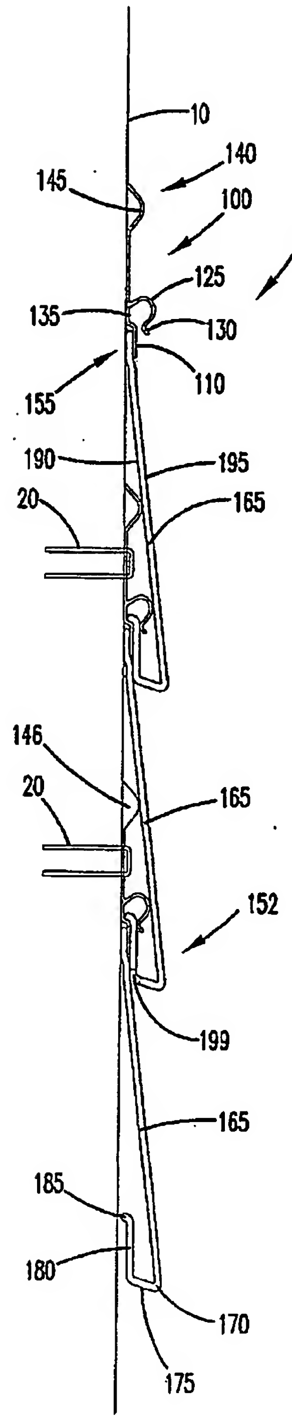
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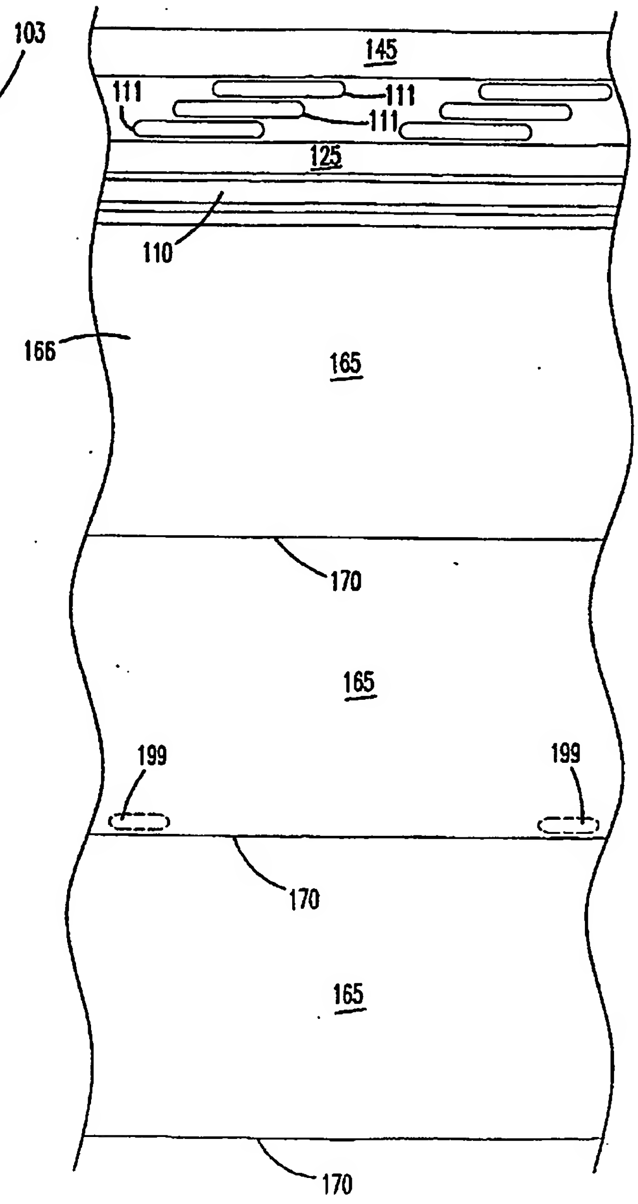
FIG. 1D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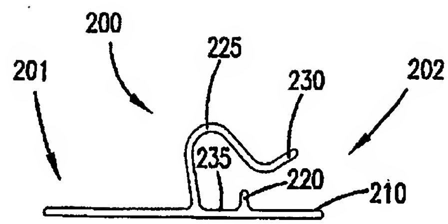
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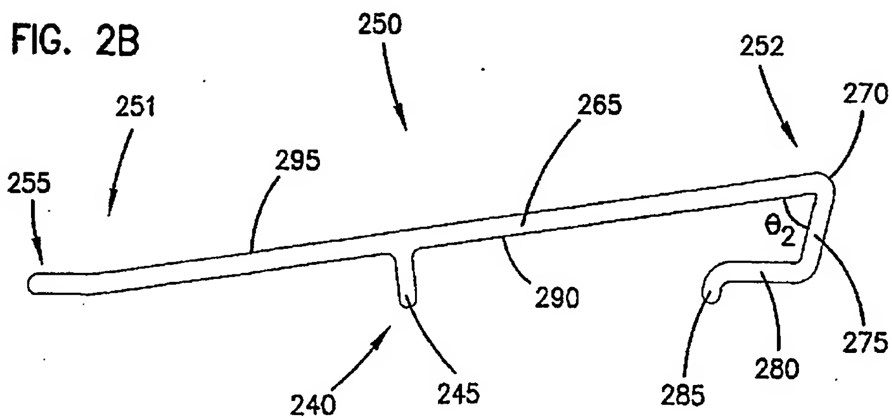
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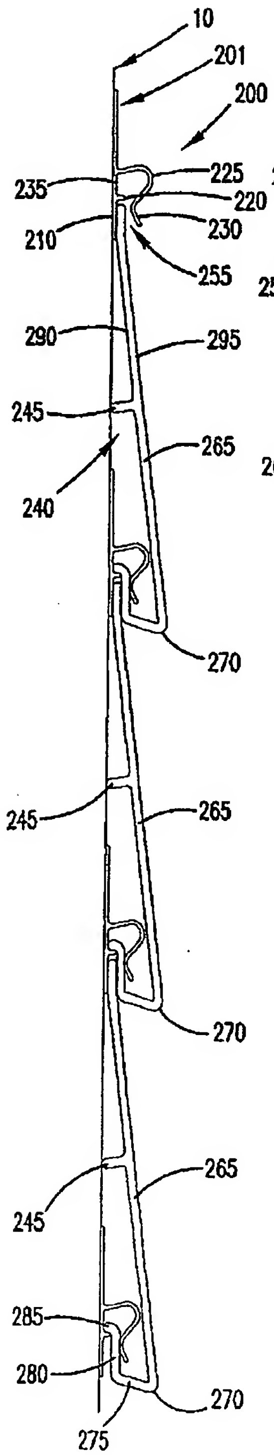
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FIG. 2D

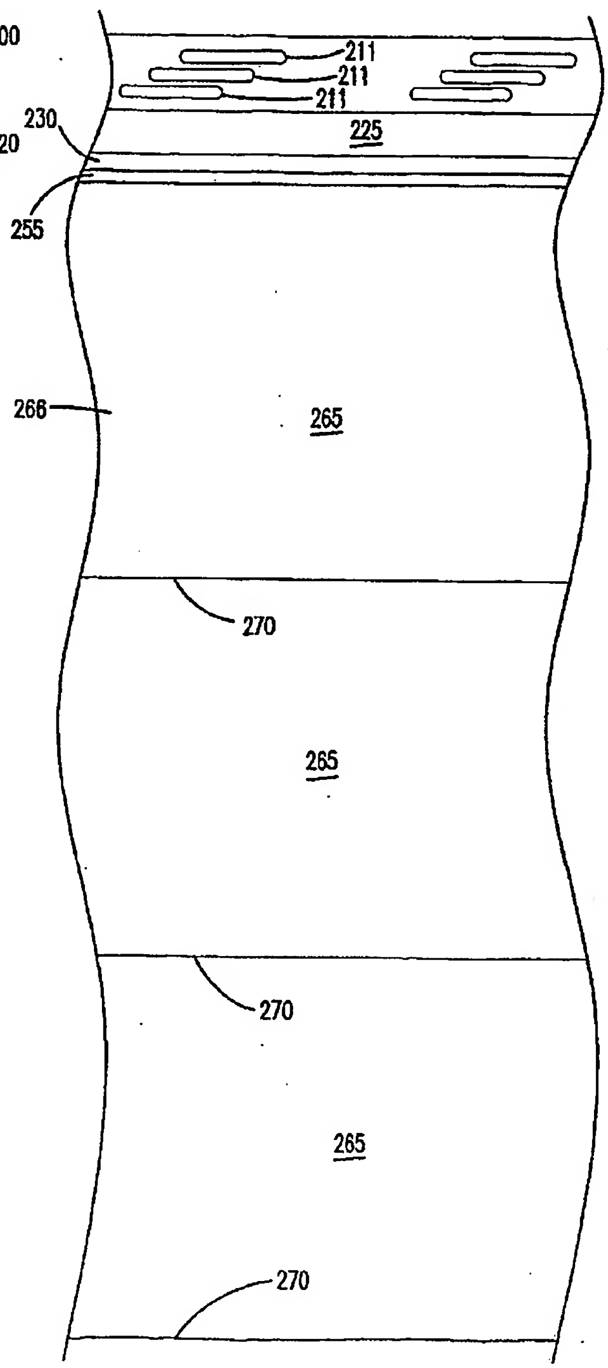
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FIG. 3A

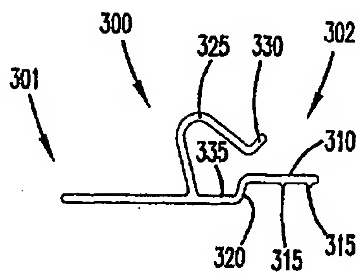
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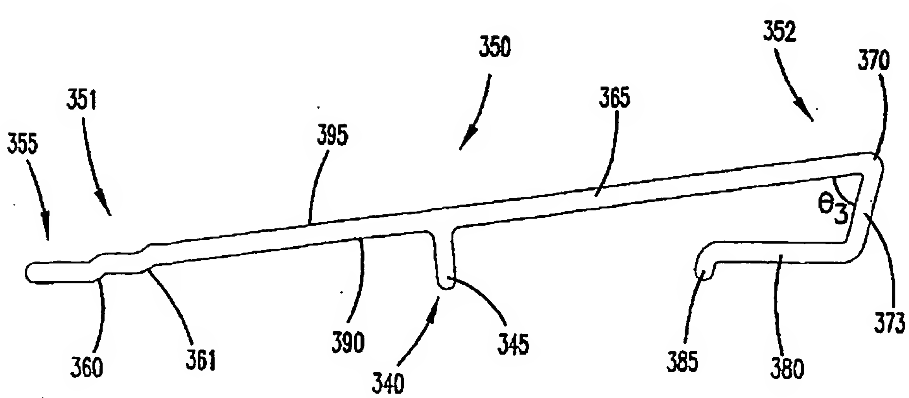
FIG. 3B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θ_3
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FIG. 3C

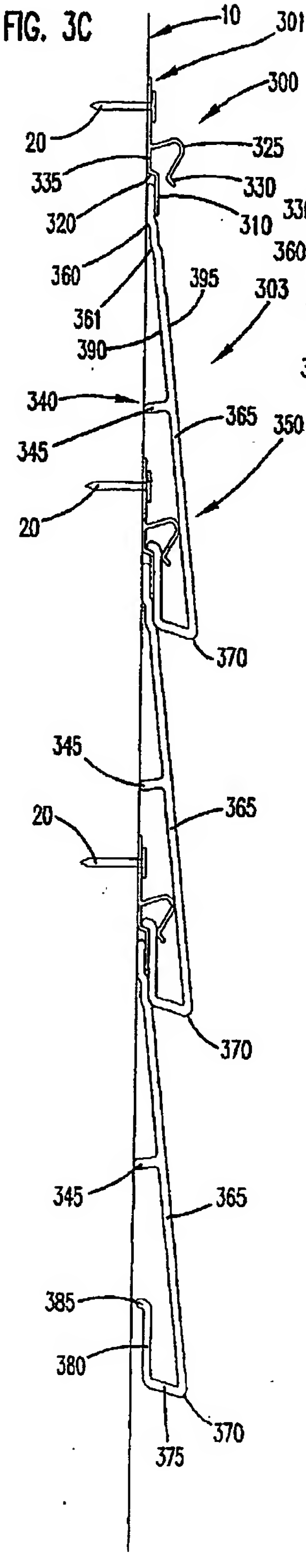
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FIG. 3D

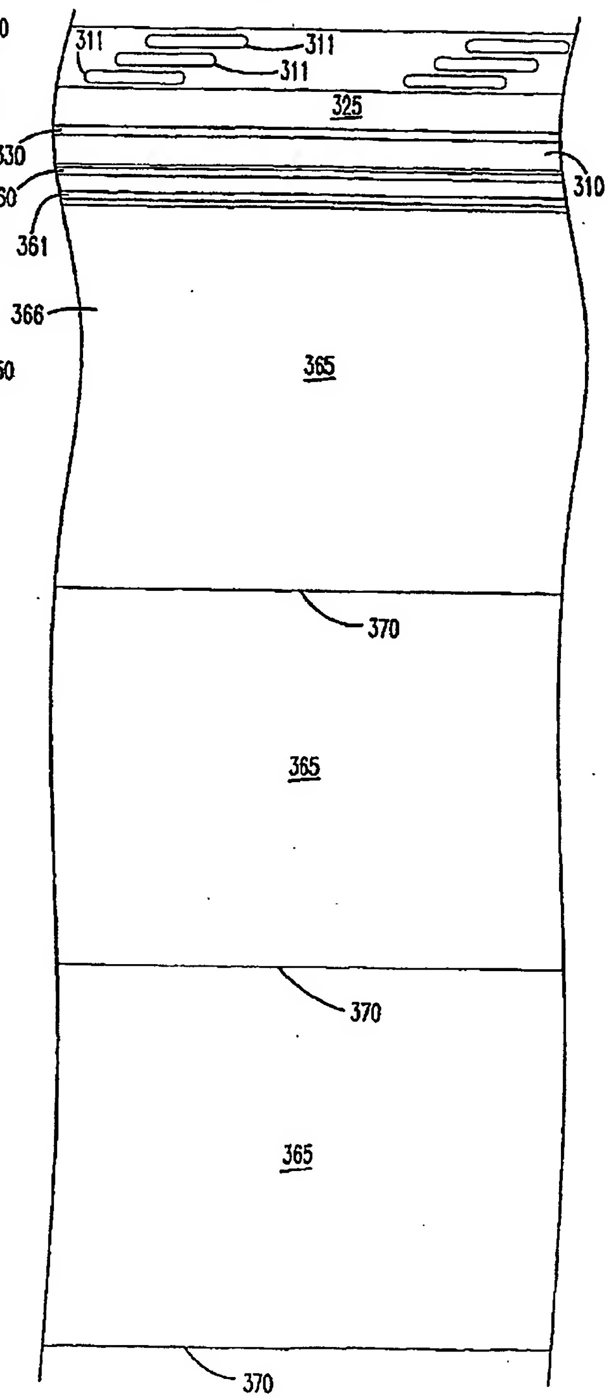
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FIG. 4A

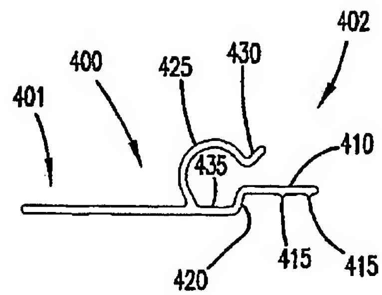
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FIG. 4B

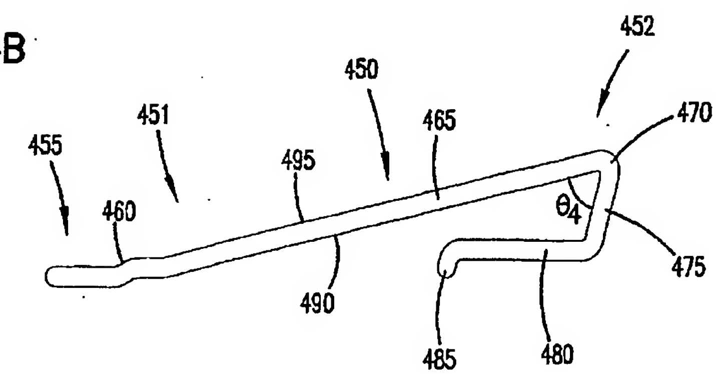
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FIG. 4C

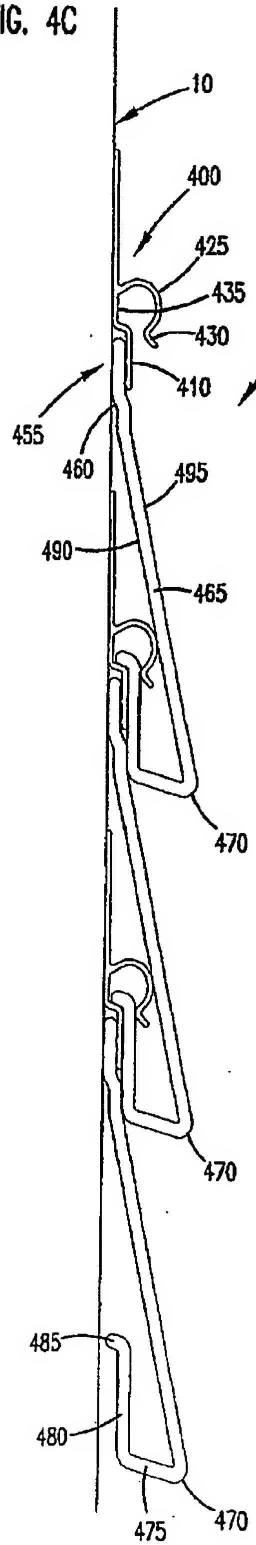
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FIG. 4D

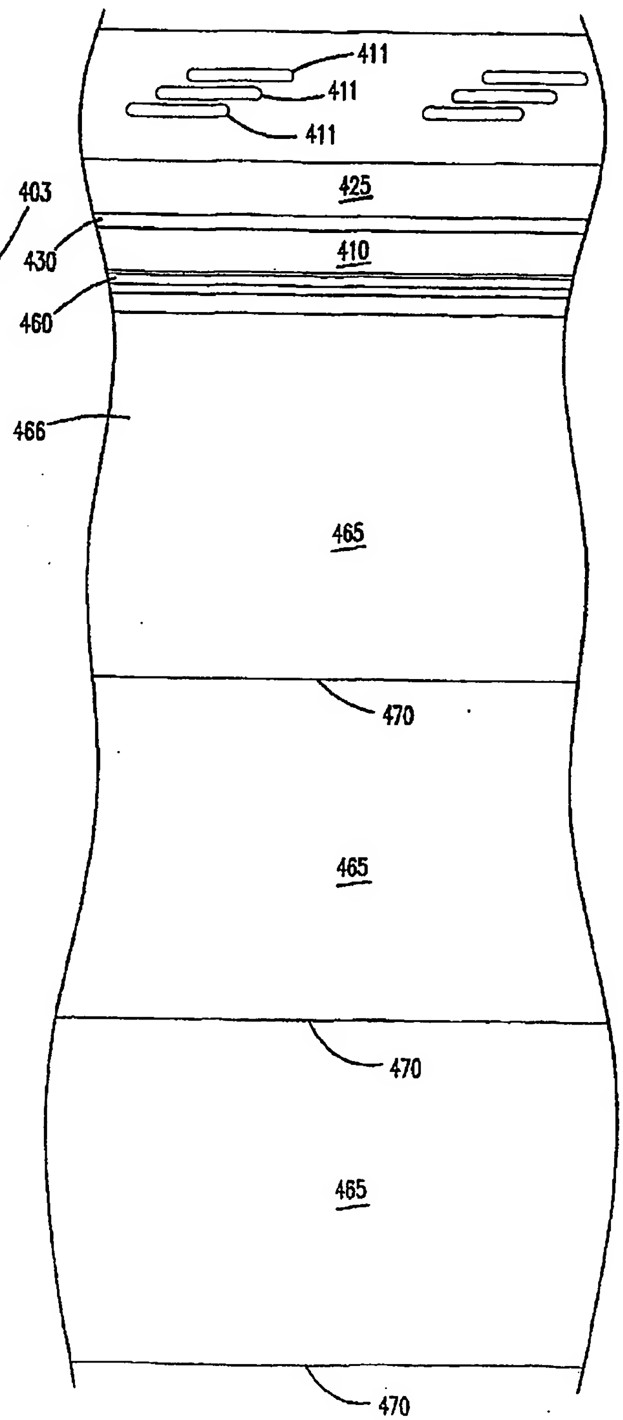
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FIG. 5A

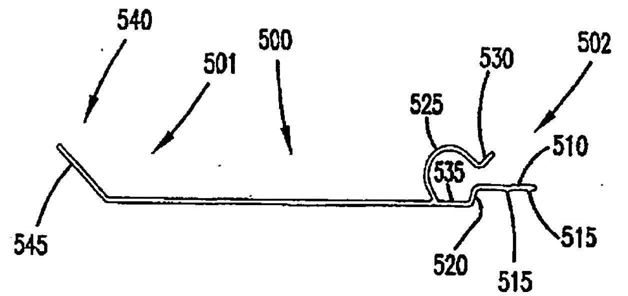
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FIG. 5B

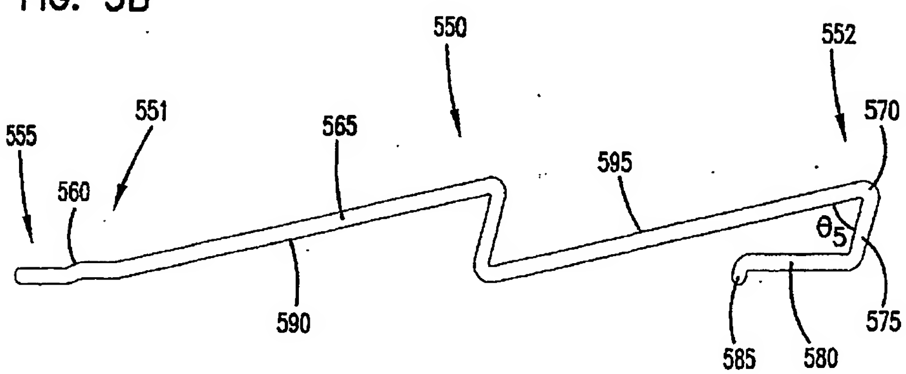
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FIG. 5C

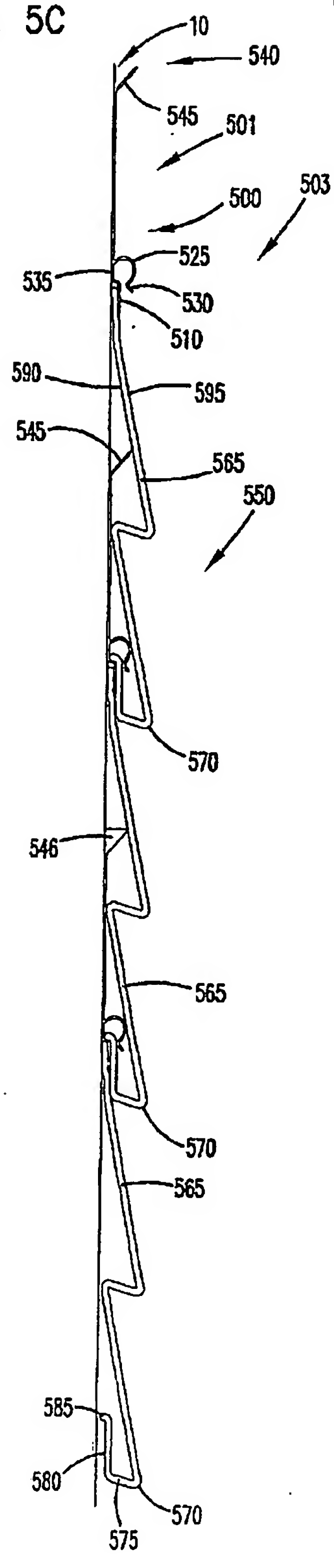
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FIG. 5D

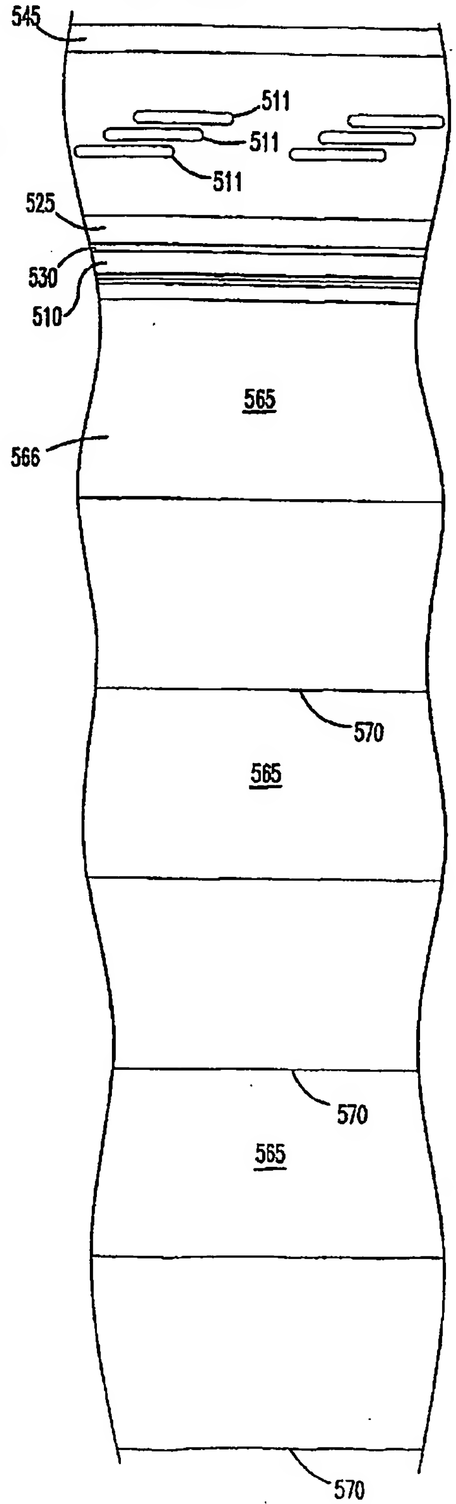
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FIG. 6A

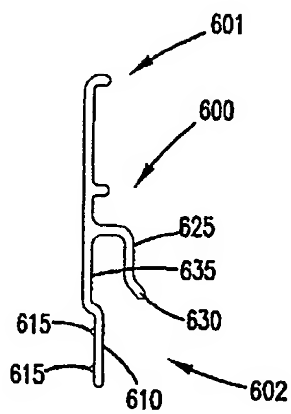
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FIG. 6B

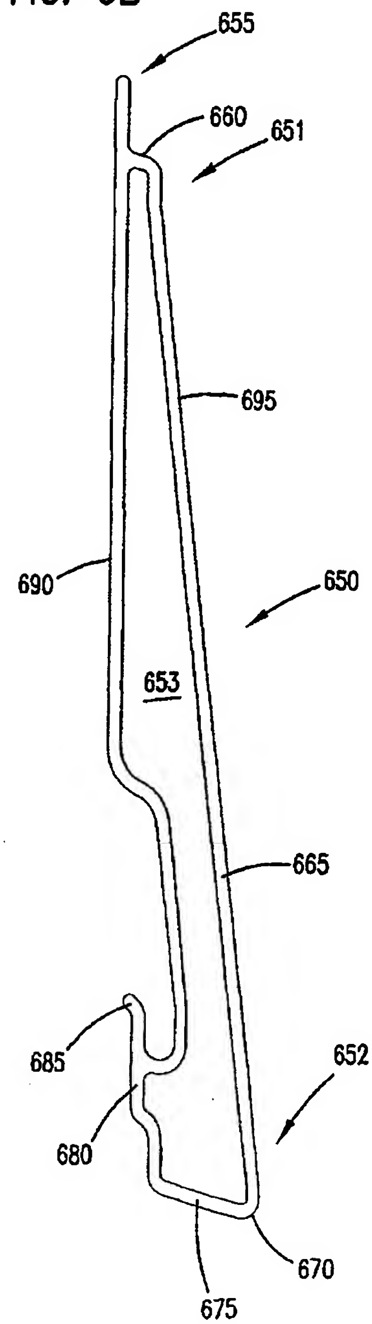
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FIG. 6C

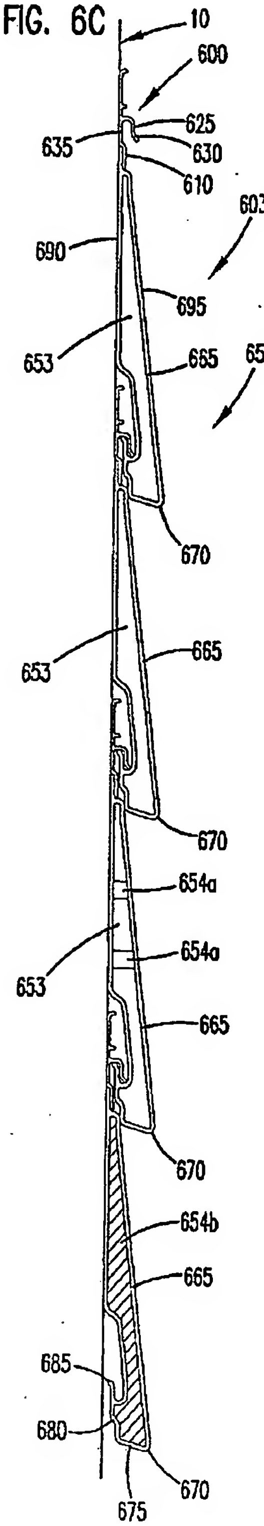
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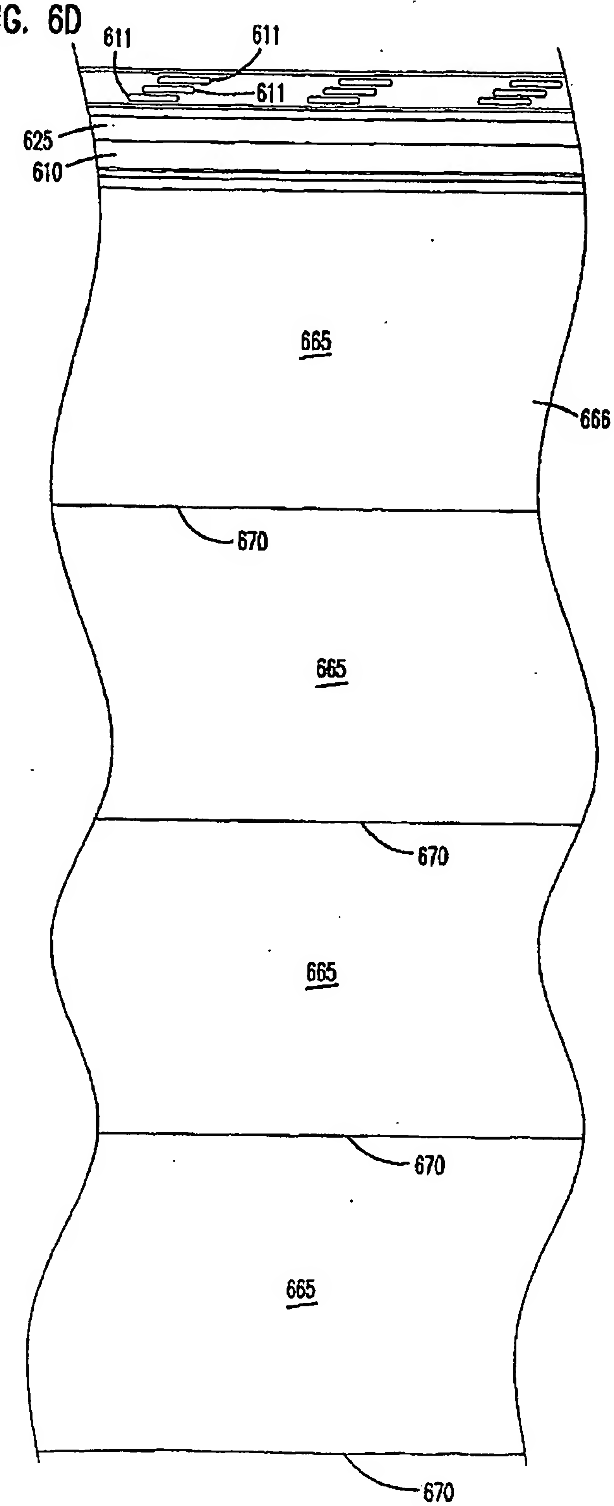
FIG. 6D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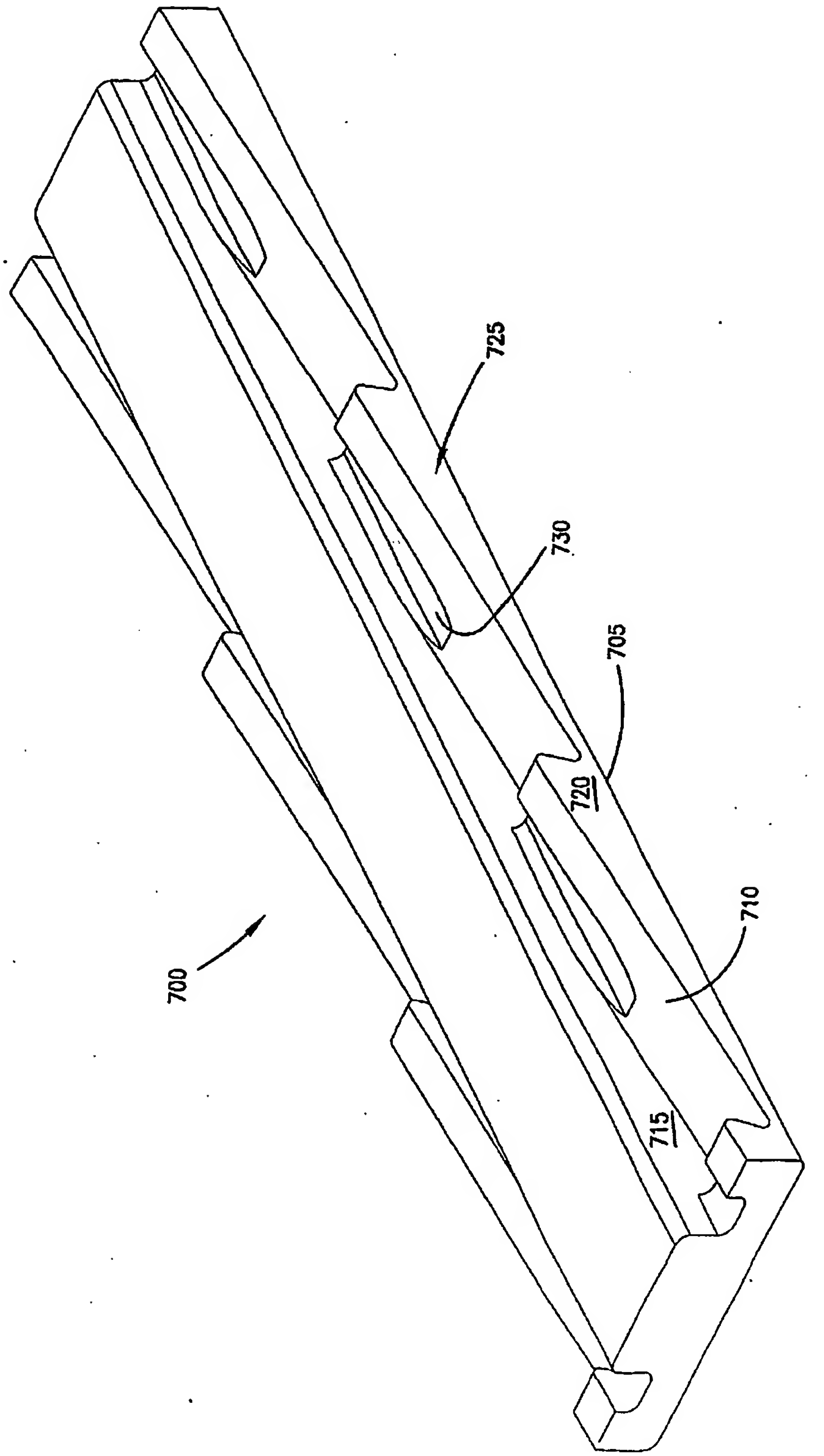


FIG. 7A

FIG. 7B

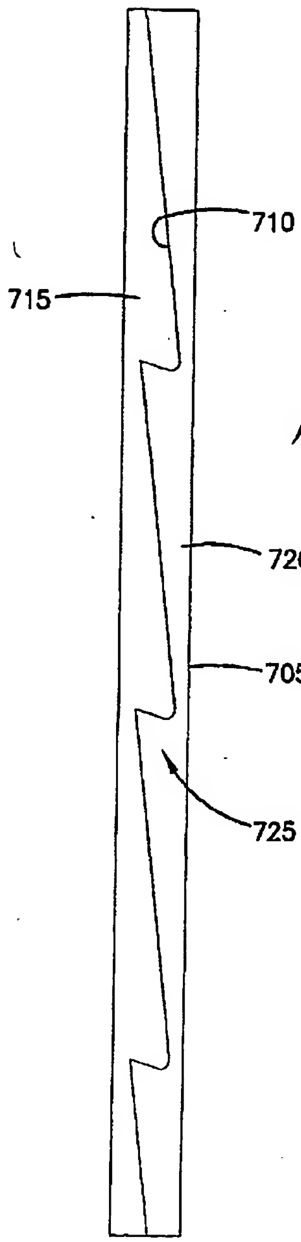


FIG. 7C

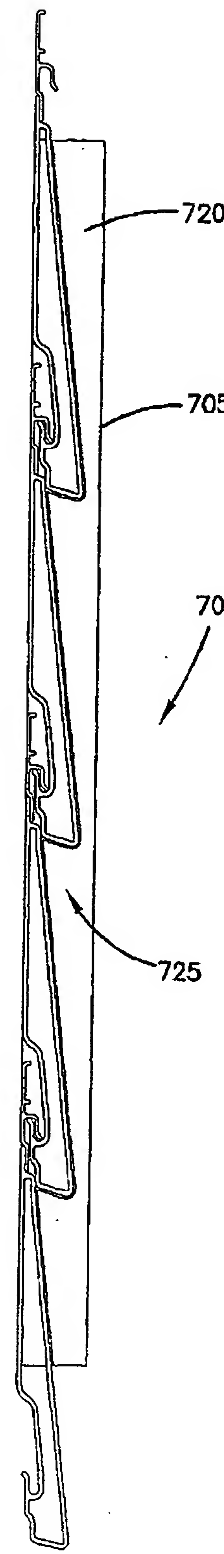


FIG. 7D

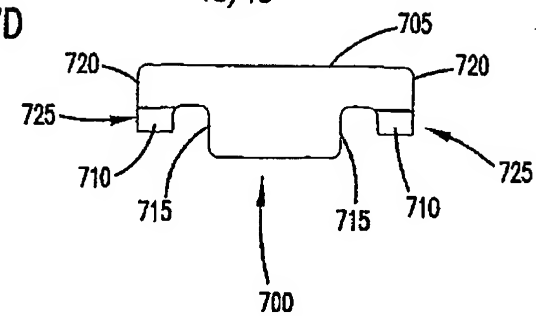


FIG. 7E

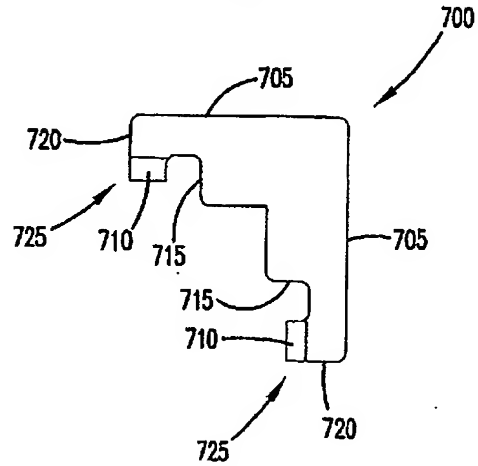


FIG. 7F

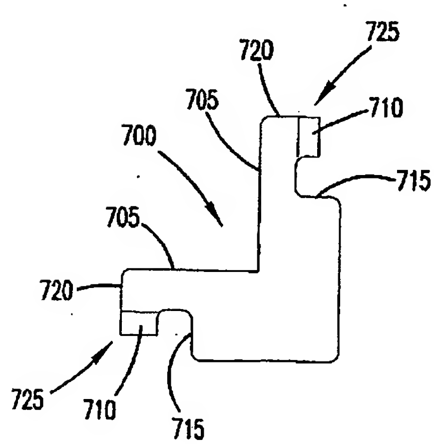


FIG. 7G

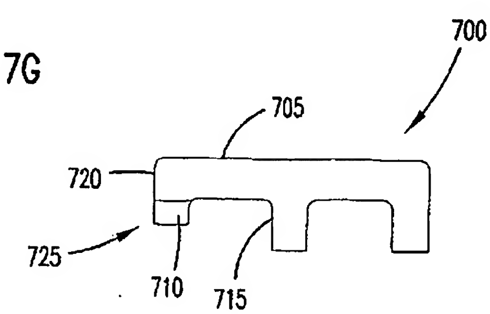


FIG. 8A

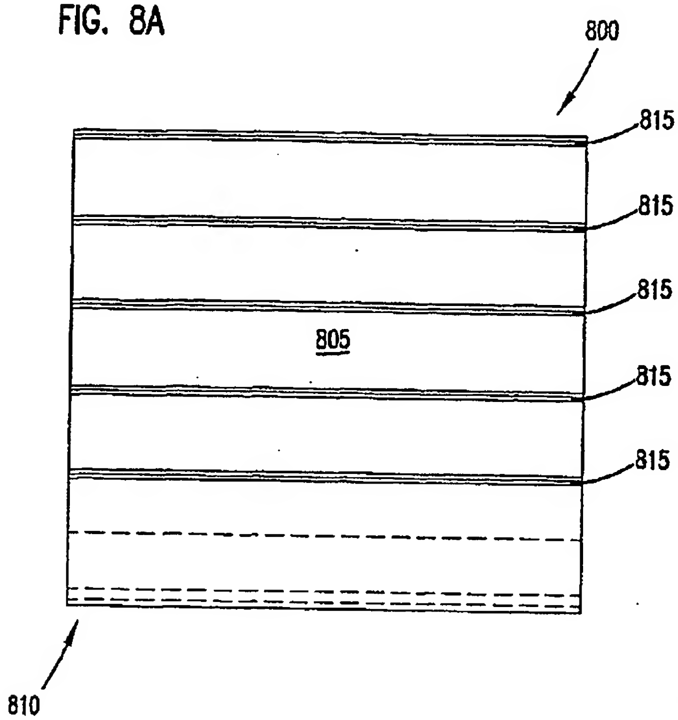


FIG. 8B

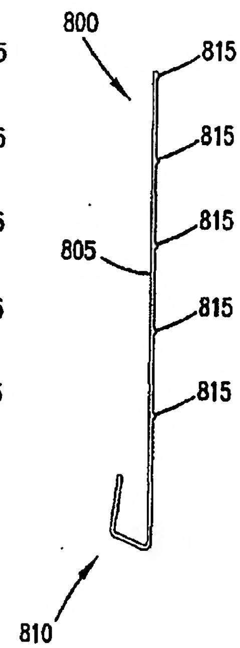


FIG. 9A

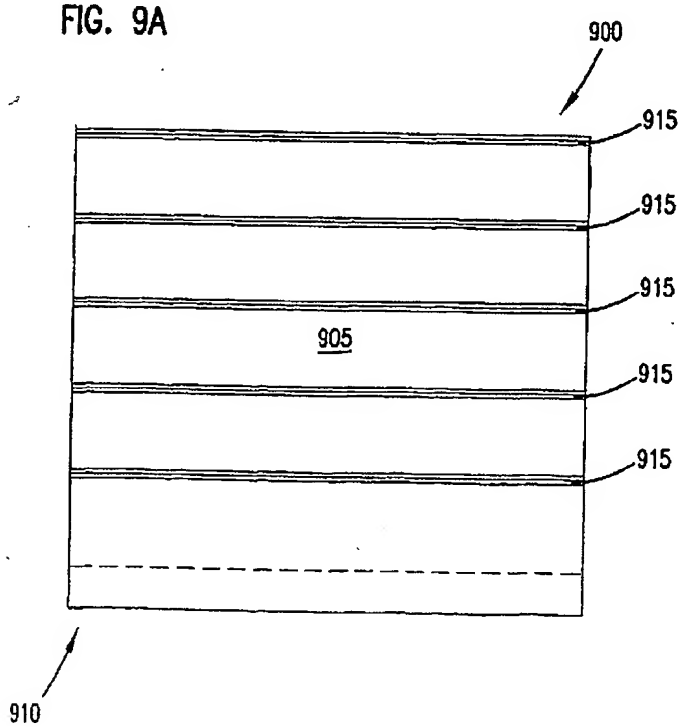
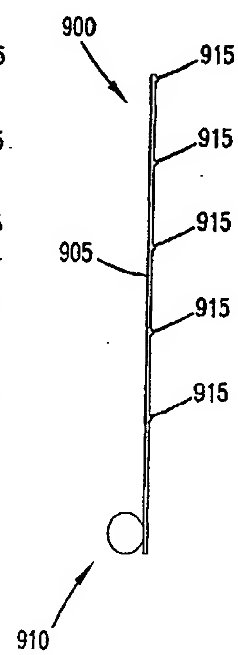


FIG. 9B



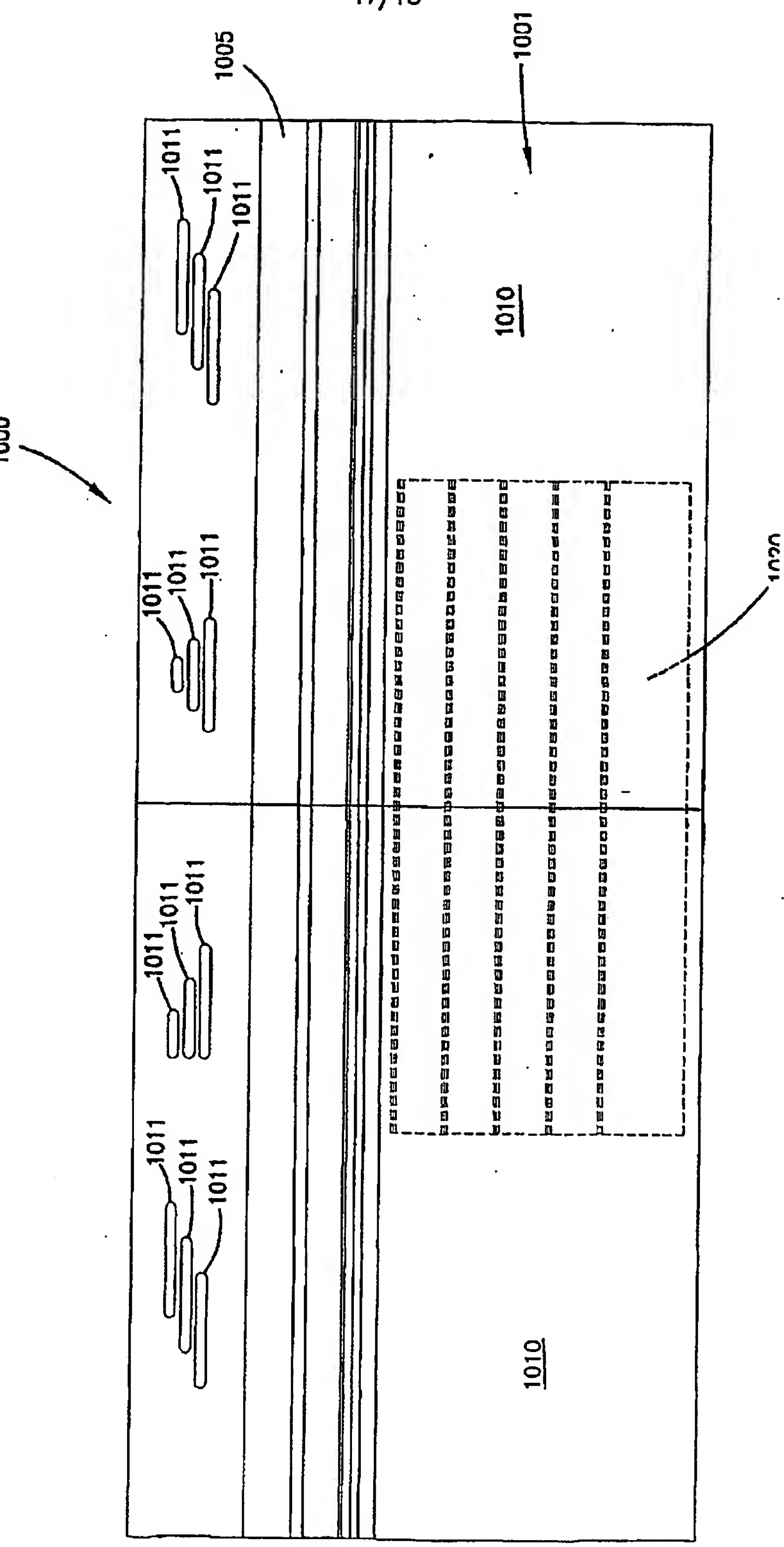

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FIG. 10

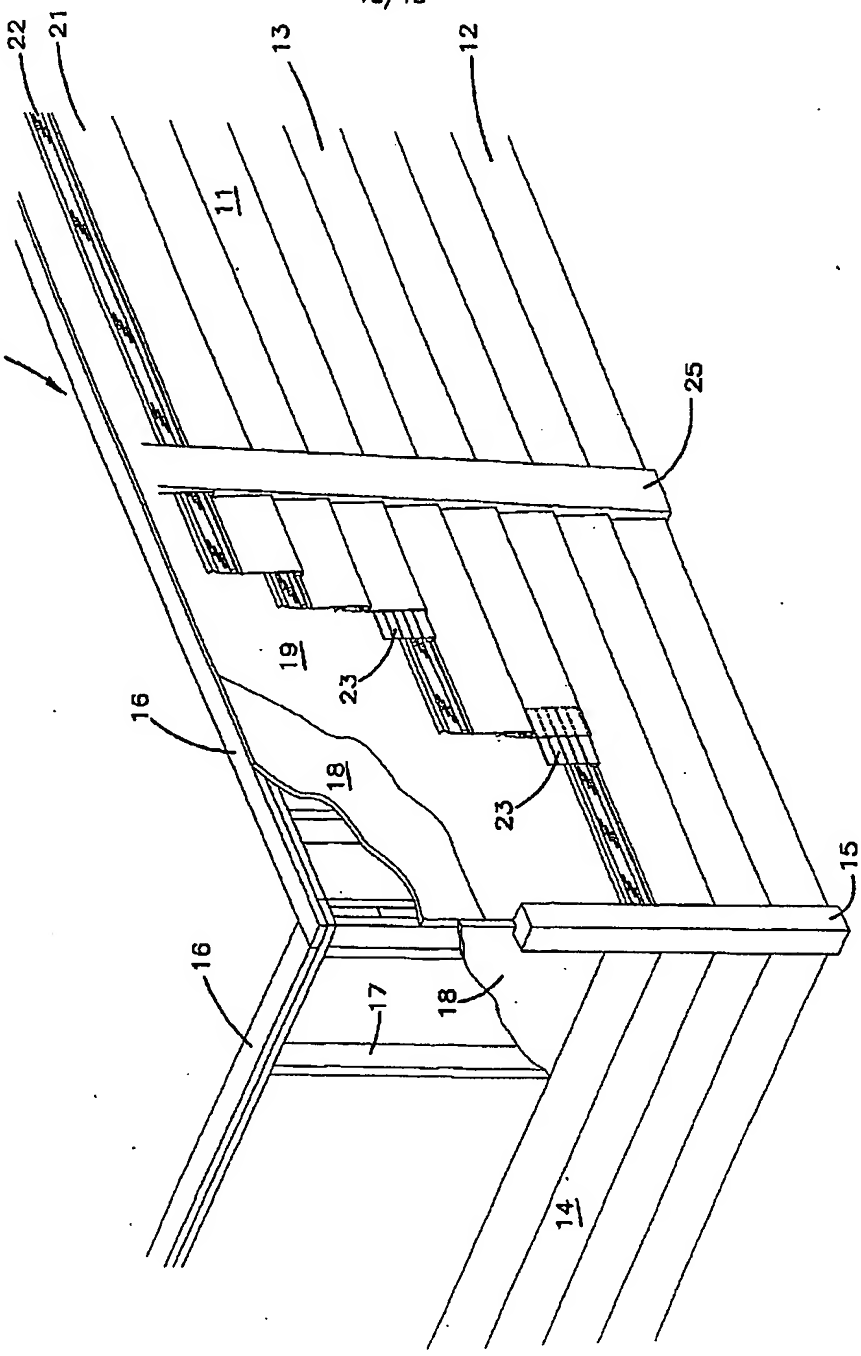


FIG. 11

INTERNATIONAL SEARCH REPORT

Intern al Application No
PCT/US 01/00936

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E04F13/08 E04F13/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E04F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category°	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6 122 877 A (HEIKKILA KURT E ET AL) 26 September 2000 (2000-09-26) the whole document	1-74, 115-128
Y	US 6 134 855 A (BECK DAVID H) 24 October 2000 (2000-10-24) column 2 -column 7; figures 2-25	1-74, 115-128
A	US 3 417 531 A (JONES ROBERT B) 24 December 1968 (1968-12-24) column 1; figures 1,2	1
A	US 4 096 679 A (NAZ PAUL) 27 June 1978 (1978-06-27) column 3, line 29 -column 4, line 32; figures 1,2	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 June 2001	10. 10. 01

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Bouyssy, V

INTERNATIONAL SEARCH REPORT

ᵢnal application No.
PCT/US 01/00936

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-74, 115-128

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-74 and 115-128

   A siding unit comprising a siding profile made of thermoplastic-biofiber composite material and an upper flange made of thermoplastic polyester, which upper flange being fastened to the siding profile.

2. Claims: 75-114

   A siding unit comprising a siding profile and an upper flange, wherein the upper flange has been fastened to the siding profile.

3. Claims: 129-131

   A building interface trim unit with a serrated edge.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/00936

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 6122877	A	26-09-2000	CA	2238887 A1	30-11-1998
US 6134855	A	24-10-2000	US	5887403 A	30-03-1999
			US	5729946 A	24-03-1998
			US	5857303 A	12-01-1999
			US	6000185 A	14-12-1999
			BR	9705300 A	25-05-1999
			CA	2217914 A1	08-04-1999
			JP	11124949 A	11-05-1999
US 3417531	A	24-12-1968	NONE		
US 4096679	A	27-06-1978	NONE		

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 October 2002 (17.10.2002)

PCT

(10) International Publication Number
WO 02/081842 A1

(51) International Patent Classification⁷: E04F 13/16, B32B 13/02

(21) International Application Number: PCT/US02/10609

(22) International Filing Date: 3 April 2002 (03.04.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/281,195 3 April 2001 (03.04.2001) US

(71) Applicant *(for all designated States except US)*: **JAMES HARDIE RESEARCH PTY LIMITED** [AU/AU]; Level 1, Research & Product Development Building, 10 Colquhoun Street, Rosehill, New South Wales 2142 (AU).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **BLACK, Andrew, J.** [AU/US]; 7425 Butterfield Place, Rancho Cucamonga, CA 91730 (US). **PENG, Weiling** [CA/US]; 10757 Lemon Avenue, Apartment 1927, Alta Loma, CA 91737 (US).

(74) Agent: **DELANEY, Karoline, A.**; KNOBBE, MARTENS, OLSON & BEAR, LLP, 620 Newport Center Drive, 16th Floor, Newport Beach, CA 92660 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EC, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

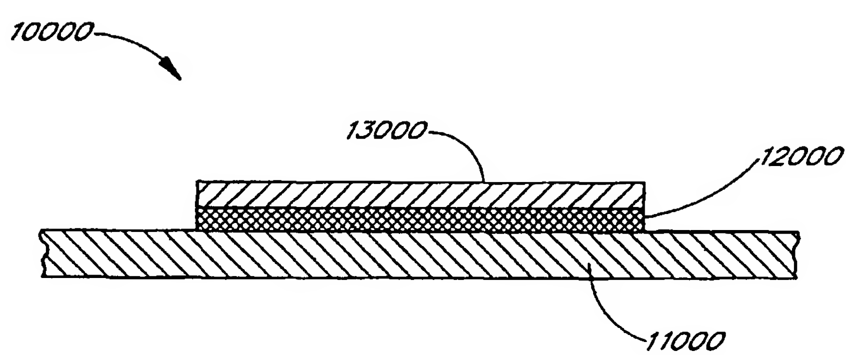
(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:
— *of inventorship (Rule 4.17(iv)) for US only*

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: REINFORCED FIBER CEMENT ARTICLE, METHODS OF MAKING AND INSTALLING



(57) Abstract: In one embodiment, a reinforced fiber cement article comprising a fiber cement piece and a reinforcing fixture bonded to a portion of the fiber cement piece for improving the performance, strength and durability of the fiber cement piece. The reinforcing fiber cement article could be used as or in conjunction with a siding plank assembly, which further comprises an interlocking feature that allows the siding plank to be stacked with other siding planks in a manner such that a uniform and deep shadow line is created. The interlocking feature sets the gauge of the exposed plank face and allows for leveling of the plank during installation. The reinforcing fixture could also serve as a thick butt piece or a plastic spline that produces a deep shadow line. A cementitious adhesive is used to bond the reinforcing fixture to the fiber cement piece.

WO 02/081842 A1

REINFORCED FIBER CEMENT ARTICLE, METHODS OF MAKING AND INSTALLING

Priority Information

[0001] This application claims priority to U.S. Provisional Patent Application Number 60/281,195, filed April 3, 2001, the entirety of which is incorporated by reference herein.

Background of the Invention

Field of the Invention

[0002] This invention in one embodiment relates to a fiber cement article that is locally reinforced by a material to assist in the handleability, performance and durability of the article.

Description of the Related Art

[0003] The market for fiber cement siding for new home construction and home refurbishing markets in the United States is presently strong, due in large part to favorable economic conditions and the durability of fiber cement.

[0004] Siding materials have traditionally been either solid or thin resilient materials. Vinyl and aluminum are two common examples of thin resilient siding materials. Vinyl siding is a thin resilient material that is shaped into the desired profile in a plastic state after extrusion of a compounded hot melt. Vinyl siding is commonly about 0.040 to 0.080 inches thick. However, vinyl presents problems as a plank material because it has a high rate of thermal expansion, which is undesirable for a product exposed to a wide range of temperatures. Aluminum siding is another example of a thin shaped product and typically has a thickness of about 0.010 to 0.030 inches. The vinyl and aluminum profiles often have an installed shape similar to traditional solid wood siding, but often include an interlocking feature to assist with the ease of installation. The interlocking profiles are usually engaged in an upward motion against gravity.

[0005] It is aesthetically pleasing for siding materials in the form of horizontal planks or laps to have a strong "shadow line" or perceived thickness such that individual planks can be discerned from a distance. This is evident from the design trends of thin vinyl or aluminum siding panels, which can be molded or extruded to give the appearance of thick, individual wood planks.

[0006] There are a number of different solid siding materials that are used in the construction and refurbishing industry. Wood siding, hardboard and fiber cement siding are examples of commonly used solid siding materials. Wood tends to lack durability and is susceptible to burning and termite attack and is not sufficiently durable in moist environments, e.g., it rots upon prolonged exposure to water. The siding shapes of solid materials are usually formed by saw cutting, machining or routing from a starting rectangular shape. A thick shadow-line or thick bottom edge of a solid siding is usually attained by starting with a solid rectangular shape of at least the thickness of the finished bottom edge of the siding. The solid siding is then machined or cut into the desired structure

[0007] While panels and planks made from wood, wood composites, and fiber-reinforced cementitious materials are inherently solid and thick, further increases in thickness of the fiber cement are not practical for reasons of material cost, weight and handling characteristics of long siding planks. Rather, an assembly that allows the use of less material while maintaining perceived thickness when installed would be beneficial. Thus, what is needed is a more efficient design of siding with a thick bottom edge to create the traditional deep shadow line with a more efficient use of material.

[0008] In addition, what is needed is a way to form a vertically-installed stackable siding plank that secures the bottom edge from lateral forces and has hidden nailing for improved aesthetics under the lap of the siding planks. In addition, what is needed is a stackable siding as described above with the exterior durability of fiber cement that is more easily machined than traditional medium density fiber cement. Furthermore, what is needed is a siding that installs with ease, maintains a constant gauge of plank rows along the length of the siding and between rows of siding and preferably resists penetration of wind driven rain through the plane of the siding.

[0009] The handleability of a siding plank is a combination of the weight, stiffness, and elasticity of the plank. Although a siding plank should be self-supporting when balanced flat upon a support point, thin fiber cement siding planks manufactured by traditional methods can be brittle and break during manual transport. While thin fiber cement siding planks could be transported by handling the edges of the planks, this slows the installation process. Therefore, what is needed is a way to improve the handleability of thin fiber cement planks.

[0010] Resistance to the effects of water and biological attack, low density, and good dimensional stability make fiber cement useful in residential and commercial building applications. However, the tensile strength of fiber cement is low relative to other building materials such as steel, aluminum, wood, and some engineered plastics. The range of application for fiber cement products could be greatly extended if fiber cement articles could be reinforced in key areas where additional tensile or impact strength is required for a specific application. What is needed is a way to provide localized reinforcement to fiber cement articles.

Summary of the Invention

[0011] In one preferred embodiment of the present invention, a reinforced article is provided that is comprised of a piece of fiber cement having a front surface and a back surface and a reinforcing fixture bonded along a length of at least one of the front surface and the back surface. Attaching the reinforcing fixture to the piece of fiber cement improves the strength of the fiber cement article and improves the durability and handleability of thin pieces of fiber cement. The reinforcing fixture can include, but is not limited to, a metal foil, woven metal mesh, polymer film, polymer fabric mesh, or a mesh nailing skirt. The reinforcing fixture preferably has a higher tensile strength than that of the fiber cement, and in one embodiment, is made of a less rigid material than that of the fiber cement. Preferably the reinforcing fixture is bonded to the fiber cement piece by a high shear adhesive. In one embodiment, wherein the fiber cement article is provided with a foil backing bonded to it using a durable high-shear adhesive, the foil backing functions as a heat reflecting

fixture. In another embodiment, a multiple lap fiber cement article is provided that includes at least one fiber cement plank bonded in a overlapping fashion to another fiber cement plank using a durable, high-shear adhesive layer.

[0012] A further brief description of other embodiments that may be used in conjunction with the foregoing embodiments is presented below.

[0013] In one aspect, a fiber cement (FC) siding plank having an interlocking feature is provided that allows siding planks to be stacked in a manner that creates a uniform and deep shadow line and secures the planks against lateral forces by blind nailing instead of face nailing. Preferably, the interlocking feature also helps set the horizontal gauge of the exposed plank face and allows for leveling of the planks during installation.

[0014] In one embodiment, the interlocking feature of the FC siding plank comprises matching lock and key cutouts on opposite ends of the plank. Preferably, the lock and key use gravity to help mate two fiber cement siding planks tightly and uniformly so as to maintain consistent gauge and overlap and create a uniform shadow line without face nailing. The plank is secured from lateral forces by hidden nailing under the lap of the adjacent plank. Preferably, the FC siding plank is low-density and can be easily machined.

[0015] Furthermore, the siding plank may include a built-in fixing indicator that allows the installer to quickly determine the proper region to affix the nail. Preferably, the fixing indicator is formed on the FC siding plank using an extrusion process so that the fixing indicator is formed cost-effectively along with the FC siding plank. The fixing indicator ensures proper placement of the fixing device within a predetermined nailing region. The predetermined nailing region on the siding plank is preferably the overlap region with the adjacent plank so that the nail or other fastener can be hidden from view. Moreover, fixing voids or hollows can also be formed beneath the fixing indicator to relieve stress that can lead to break out and cracking of the product when nailed or fastened to wall framing.

[0016] In another embodiment, the interlocking feature of a FC siding plank comprises an oversized "V" style lock and a key tip. The lock can be separately attached to the FC plank or integrally formed as part of the plank. Preferably, the siding plank interlocks with an adjacent plank by locking the oversized "V" style lock into the key tip on an upper edge of the adjacent plank. The lock maintains a constant gauge and overlap between the planks so as to create a uniform and thick shadow line. The oversized "V" style lock design allows for non-uniform flatness of a framed wall and maintains a constant gauge of plank rows along the length of the siding and between rows of siding. The plank is secured from lateral forces by hidden nailing under the lap of the plank. Preferably, the lock also comprises compressible regions, which allows the planks to be easily interlocked during installation and provides lateral compensation for non-planar mounting surfaces. The compressible material can also act as a seal against wind and rain.

[0017] In another embodiment, the interlocking feature of a siding plank comprises a square lock system. Preferably, the square lock system comprises a square lock, a butt piece, and an overlap guide. It can be appreciated that the square lock system, as well as the other systems described herein, can be

applied to a variety of siding planks, including but not limited to FC planks. Preferably, the square lock is configured to fit over an upper edge of an adjacent plank in a manner such that a small gap may be maintained between the lock and the upper edge of the adjacent plank to accommodate variable gauge height. The square lock helps level the planks during installation and allows for small variations in the siding installed gauge while reducing lateral movement of the planks. The square lock can be separately bonded to the siding plank or formed as an integral part of the FC siding plank. Preferably, the square lock has one or more dove tail grooves to enhance the bonding between the lock and the siding plank. The square lock design preferably resists penetration of wind driven rain through the plane of the siding.

[0018] Furthermore, the siding plank of one preferred embodiment may also include an apparatus for reducing capillary action between adjacent overlapping planks. Preferably, the apparatus comprises a capillary break formed by adding to or indenting the material of the interlocking device of the siding plank assembly. Preferably, the capillary break is placed between adjacent siding planks to stop the rise of water in the plank overlap region and thus provide additional moisture protection to the exterior barrier wall and siding interior without leaving a gap that is attractive to insects.

[0019] In another aspect, a lightweight, two-piece FC siding plank is provided that produces a uniform and thick shadow line when stacked with other planks. The two-piece FC siding plank generally comprises a main plank section and a FC butt piece that is bonded to the main plank section and extends partially over a back surface of the main plank section. The butt end piece reinforces the main plank section to increase the overall rigidity of the plank. The thickness of the butt piece also helps to create a deeper shadow line on adjacent planks. Preferably, the butt piece is separately bonded to the main plank section so that the enhanced shadow line is created without having to machine a single rectangular FC material to form the equivalent structure.

[0020] The adhesive used to bond the two pieces together can be polymeric, cementitious, organic or inorganic or a combination thereof such as polymer modified cement. The adhesive may also have fiber added to increase the toughness of the adhesive joint. In one embodiment, the main plank section is bonded to the butt piece using a fast setting, reactive hot-melt polyurethane adhesive. Preferably, the polymeric adhesive establishes a very quick bond which enables a machining operation to follow the bonding operation in a single manufacturing line rather than having to wait for the adhesive to set and then machine in a separate operation.

[0021] In another embodiment, the main plank is adhered to the butt piece using a cementitious adhesive that is compatible with fiber cement materials and thus can be bonded to the FC main plank while in a green state and co-cured with the FC material to form a durable bond. Preferably, a pressure roller system or a hand roller is used to bond the main siding plank to the butt piece. A hydraulic press can be used to bond the two pieces if the siding plank or butt piece has uneven surface. Additionally, in other embodiments, the two-piece FC siding plank can also be formed by extrusion in which a single piece of FC

plank with an integrally formed butt piece is formed. Furthermore, the main plank section and the butt piece can have hollow centers to further reduce the weight of the siding plank.

[0022] In another embodiment, a two-piece FC siding plank includes an interlocking feature that mates two FC siding planks tightly and uniformly without requiring a visible nail or other fastener to fasten the overlapping region of the two planks. Preferably, the interlocking feature comprises a key formed on the main plank and a lock formed on the butt piece. The key fits into the lock and, with the help of gravity, interlocks adjacently mounted planks. The lock and key set the gauge of the exposed plank face without requiring frequent measuring.

[0023] In another aspect, an adhesive composition is provided that is used to bond cementitious materials, such as fiber cement planks. Preferably, the adhesive composition includes cement, silica, a thickener, and water, and may include organic or inorganic fibers. The adhesive composition can be used to bond flat sheet, plank or profiled cementitious bound building products. The adhesive can also be used to bond different density cementitious materials together to form a composite panel. In one embodiment, the adhesive is used to bond two fiber cement siding planks together. Preferably, the adhesive is applied to the fiber cement planks in a green state so that the FC and FC adhesive cure together. Preferably, the adhesive does not deteriorate under autoclave processing conditions and thus can be used to bond FC planks prior to autoclaving.

[0024] In another aspect, a siding plank having a spline is provided that increases the handling, strength and stiffness of the siding plank and produces a uniform and thick shadow line. The spline can be a shaped piece of one or more materials, and is preferably made of lightweight materials such as plastic, foamed plastic, metal or fiber reinforced plastic. The spline is preferably attached to the main body of the siding plank to add function and/or aesthetics to the plank. Preferably, the spline improves the handleability and toughness of the siding plank. With the spline, the thickness of a medium density FC plank can be reduced without sacrificing handleability. For instance, FC planks that are about ¼ to 3/16 inch thick can still be handleable without breaking at 16 ft length when the spline is attached to the plank. This provides a lightweight FC siding plank of increased length that is easier to handle and requires less material to manufacture.

[0025] In one embodiment, the spline comprises a butt and a lock and is designed for use in combination with a FC plank. Preferably, the butt is thick so that a deep shadow line can be produced when the planks are stacked together. Preferably, the lock is an angled lock that is configured to help secure the plank to adjacent planks in the stack. Preferably, the spline is bonded to the to the FC plank with an adhesive and the spline has one or more dovetail grooves in the adhesive surface area to strengthen the bond between the spline and the plank. In another embodiment, the spline has an overlap guide that helps set the gauge of the exposed plank face. However, it can be appreciated that the spline does not have to include a lock, an overlap guide or dovetail grooves.

[0026] It will be appreciated that the preferred embodiments of this invention are not limited to siding planks or interlocking features to mount one plank adjacent another. Thus, in one embodiment a fiber cement article, which may or may not be a siding lank, is provided having a reinforcing fixture adhered thereto. The reinforcing fixture provides localized reinforcement to areas of the article that requires additional strength and/or support.

[0027] These and other objects and advantages will become more fully apparent from the following description taken in conjunction with the accompanying drawings.

Brief Description of the Drawings

[0028] Figure 1A shows an isometric view of one embodiment of a FC siding plank with a back surface visible.

[0029] Figure 1B shows an isometric view of FC siding plank with a front surface visible.

[0030] Figure 2 shows an end view of FC siding plank.

[0031] Figure 3 shows a siding system of FC siding planks affixed to a mounting surface.

[0032] Figure 4 shows a method of installing a siding system according to one embodiment of the present invention.

[0033] Figure 5 shows an isometric view of a section of an FC plank in accordance with another embodiment of the present invention.

[0034] Figure 6 shows an end view of an extrusion die used to form the plank of Figure 5.

[0035] Figure 7 shows a cross-sectional view of a siding plank system in accordance with the embodiment of Figure 5 affixed to a mounting surface.

[0036] Figure 8 shows an isometric view of a section of an FC plank in accordance with another embodiment of the present invention.

[0037] Figure 9A shows an isometric vertical view of a two-piece FC plank in accordance with another embodiment of the present invention.

[0038] Figure 9B shows an isometric horizontal view of the two-piece FC plank of Figure 9A.

[0039] Figure 10 shows a side view of a first end of a butt piece used to form the plank of Figure 9A.

[0040] Figure 11A shows an isometric view of the two-piece plank of Figure 9A formed using a pressure roller system.

[0041] Figure 11B shows an end view of the two-piece plank and pressure roller system of Figure 11A.

[0042] Figure 12 shows one method for making a two-piece plank.

[0043] Figure 13 shows another method for making a two-piece plank.

[0044] Figure 14A shows an isometric view of a two-piece plank formed using a hand roller.

[0045] Figure 14B shows an end view of the two-piece plank and hand roller of Figure 14A.

[0046] Figure 15 shows a method of making a two-piece plank assembly using an adhesive.

[0047] Figure 16 shows a method of making a cementitious adhesive for bonding FC materials.

[0048] Figures 17A and 17B show schematic views of a Hobart style low shear mixer containing adhesive formulation in accordance with the method of Figure 16.

[0049] Figure 18 shows a dewatering apparatus containing mesh screens and a metal plate in accordance with the method of Figure 16.

[0050] Figure 19 shows a high shear mixer containing an adhesive formulation in accordance with the method of Figure 16.

[0051] Figure 20A shows a partial perspective view of a two-piece FC plank assembly according to another embodiment of the present invention.

[0052] Figure 20B shows a partial perspective view of a two-piece FC plank assembly rotated 90° from Figure 20A.

[0053] Figure 21 shows a side view of the plank assembly of Figure 20A.

[0054] Figure 22 shows a cross-sectional view of two installed plank assemblies of Figure 20A.

[0055] Figure 23 shows a method of the installing plank assemblies of Figure 20A.

[0056] Figure 24 shows an isometric view of another embodiment of the FC plank assembly.

[0057] Figure 25 shows a cross-section of the plank assembly of Figure 24.

[0058] Figure 26 shows a key tip on the FC plank assembly of Figure 24.

[0059] Figure 27 shows an enlarged cross-sectional view of the lock assembly on the FC plank assembly of Figure 24.

[0060] Figure 28 shows a cross-sectional view of the lock assembly of Figure 27 with approximate dimensions.

[0061] Figure 29 shows a cross-sectional view of lock assembly and key of two adjacent FC plank assemblies.

[0062] Figure 30 shows a cross-sectional view of a siding system made up of two-piece planks with oversized "V" style lock and compressible regions in accordance with Figure 24.

[0063] Figure 31 shows a method of making the plank of Figure 24 with an oversized "V" style lock and compressible regions.

[0064] Figures 32A and 32B show alternate cross-sectional views of plank designs that could utilize first and second compressible regions.

[0065] Figure 33 shows an isometric view of a section of a siding plank assembly with a locking spline in accordance with another embodiment of the present invention.

[0066] Figure 34 shows an isometric view of the plank of Figure 33.

[0067] Figure 35 shows a cross-sectional view of the plank of Figure 33.

[0068] Figure 36 shows an isometric view of the locking spline of Figure 33.

[0069] Figure 37 shows a cross-section of the locking spline of Figure 33.

[0070] Figure 38 or end view shows an end view of the locking spline of Figure 33, with approximate dimensions.

[0071] Figure 39 shows a cross-sectional view of the siding plank assembly of Figure 33.

[0072] Figure 40 shows a cross-sectional view of an alternative siding plank assembly having a locking spline with a chamfer.

[0073] Figure 41 shows a cross-sectional view of the two-piece siding plank system of Figure 33 affixed to a mounting surface.

[0074] Figure 42A shows a cross-sectional view of a plastic spline having a capillary break and dovetail grooves.

[0075] Figure 42B shows an enlarged cross-sectional view of a surface of the spline of Figure 42A having dovetail grooves.

[0076] Figure 43A shows a cross-sectional view of the spline of Figure 42A bonded to a main plank.

[0077] Figure 43B shows an enlarged cross-sectional view of the bond between the spline and main plank of Figure 43A.

[0078] Figure 44A shows a cross-sectional view of a two-piece siding plank assembly in accordance with another embodiment of the present invention.

[0079] Figure 44B shows a cross-sectional view of the two-piece siding system of Figure 44A affixed to a mounting surface.

[0080] Figure 45A shows a cross-sectional view of the two-piece siding plank assembly in accordance with another embodiment of the present invention.

[0081] Figure 45B shows a cross-sectional view of the siding system of Figure 45A affixed to a mounting surface.

[0082] Figure 46 shows the method steps for making a two-piece plank assembly using an FC siding plank bonded with an adhesive to a plastic spline.

[0083] Figure 47 shows an isometric view of a section of a siding plank assembly in accordance with another embodiment of the present invention.

[0084] Figure 48 shows an isometric view of the plank of Figure 47.

[0085] Figure 49A shows a cross-sectional view of the plank of Figure 48.

[0086] Figure 49B shows a side view of the key tip of Figure 49A.

[0087] Figure 50 shows an isometric view of the locking spline of Figure 47.

[0088] Figure 51 shows a cross-sectional view of the locking spline of Figure 50.

[0089] Figure 52 shows an end view of the locking spline of Figure 50 with approximate dimensions.

[0090] Figure 53 shows a cross-section of the siding plank assembly of Figure 47.

[0091] Figure 54 shows a cross-sectional view of an alternative siding plank assembly with a chamfer.

[0092] Figure 55 shows a cross-sectional view of the two-piece siding plank system of Figure 47 affixed to a mounting surface.

[0093] Figure 56 shows a method for making a two-piece plank assembly using an FC siding plank bonded with an adhesive to a plastic spline.

[0094] Figure 57 shows an isometric view of a section of a siding plank assembly in accordance with another embodiment of the present invention.

[0095] Figure 58 shows an isometric view of the plastic spline with a capillary break of Figure 57.

[0096] Figure 59 shows a cross-sectional view of the spline of Figure 58.

[0097] Figure 60 shows an end view of the spline of Figure 58 with approximate dimensions.

[0098] Figure 61 shows a cross-sectional view of a two-piece siding plank system showing adjacent siding plank assemblies formed in accordance with Figure 57.

[0099] Figure 62 shows an isometric view of an alternative embodiment of plastic spline with a capillary break.

[0100] Figure 63 shows a cross-sectional view of the spline of Figure 62.

[0101] Figure 64 shows an end view of the spline of Figure 62.

[0102] Figure 65 shows a cross-sectional view of a two-piece siding plank system showing adjacent siding planks formed using the spline of Figure 62.

[0103] Figure 66 shows a cross-sectional view of a reinforced fiber cement article.

[0104] Figure 67 shows a front perspective view of a reinforced fiber cement plank with a nailing skirt.

[0105] Figure 68 shows a rear perspective view of a reinforced fiber cement plank with an extruded polymer reinforcing strip.

[0106] Figure 69 shows a rear perspective view of a multi-lap fiber cement plank.

[0107] Figure 70 shows a method of making a reinforced fiber cement article.

Detailed Description of the Preferred Embodiments

[0108] Certain preferred embodiments of the invention generally relate to lightweight siding plank assemblies that are structured to secure the siding planks against lateral forces without face nailing and to create a uniform and deep shadow line. In some of these embodiments, the shape of the plank is achieved by adding a second material to a base plank to add function and/or aesthetics, such as a thick bottom edge and/or interlock. These and other features and functionality of the preferred embodiments are described in detail below.

[0109] Unlike other siding materials, fiber cement ("FC") materials have preferred qualities of non-combustibility, strength, and durability. Low-density FC has additional advantages over higher density FC

because the material is more easily machined, and its decreased weight facilitates handling and installation. Manufacture of siding planks made of low-density and medium-density FC material, as described in Australian Patent No. AU 515151 and U.S. Patent No. 6,346,146, the entirety of each of which is hereby incorporated by reference, having additional functional and aesthetic features could result in a more marketable siding plank.

[0110] One siding design, which uses a lock system, allows planks to be locked into one another without requiring extensive measurement to maintain gauge (the visible vertical distance between planks) and overlap (the vertical distance the plank overhangs the plank below) during installation. Although this lock design has many inherent advantages, this design affords little to no flexibility when being installed on a non-planar wall. Therefore, embodiments described below include a locking plank that allow the exterior siding to be installed on non-planar walls.

[0111] Moreover, certain lock designs do not function satisfactorily for small variations in gauge that are sometimes desired by installers, especially when trying to level-out inaccuracies in framing and installation around window and door openings. As a result of poorly fitted V-type lock and key siding, the plank may subsequently experience lateral movement (flapping) when subjected to wind. Rather, a lock design that allows for small variations in gauge while preventing lateral movement (flapping) when subjected to wind would be beneficial.

[0112] Furthermore, functional performance enhancements made to existing FC siding planks will bring great value to the siding plank market. For example, an alignment feature or fixing indicator, described below, adds value to FC siding planks by facilitating the installation process. Also, the appearance of nailable extruded products on the market has brought with it the need to provide nailing positions on the product to ensure proper and speedy installation. Accordingly, there is a sound business motivation to find a cost efficient way to add features such as affixing indicators to FC siding planks. Moreover, what is needed is also a way to form a stackable siding plank that secures the bottom edge from lateral forces and allows for hidden nailing under the lap of the siding planks, as described below.

[0113] Although the preferred embodiments of the present invention describe the use of fiber cement planks, it will be appreciated that other materials may be used as well. It will also be appreciated that the invention is not limited only to siding planks, but may have use in other applications as well.

I. LOW-DENSITY SIDING PLANK WITH LOCKING FEATURES AND METHOD OF INSTALLING THE SAME

[0114] At least one embodiment relates to a low density plank with locking features and methods of installing the same. In one embodiment, the siding plank is manufactured using a process, which includes but is not limited to the Hatschek process as described in U.S. Patent No. 6,346,146, the entirety of which is hereby incorporated by reference, to make low-density FC materials. Low density fiber cement typically has a density ranging from about 0.7 to 1.2 g/cm^3, whereas medium density typically has a density of about 1.3 to 1.5 g/cm^3. This embodiment includes locking features to allow siding planks to be interlocked when installed on a mounting surface (e.g., an exterior wall) as siding.

[0115] Figure 1A and Figure 1B show two isometric views of a siding plank 1100. As shown in Figure 1A, siding plank 1100 includes a back surface 1110, an end surface 1115, a key 1130, and a lock 1140. As shown in Figure 1B, siding plank 1100 further includes a front surface 1120. Table 1 shows preferred ranges of siding plank dimensions for this embodiment:

Table 1. Preferred range of siding plank dimensions

Dimension	Range
Thickness T	about 3/16-1/2 inch
Width W	about 5-12 inches
Length L	about 12-16 feet

[0116] Figure 2 shows an end view of siding plank 1100 that further describes key 1130 and lock 1140. Specifically, key 1130 further includes a key tip 1132 and makes an angle 1135 with a vertical plane. The key tip preferably forms a tier indented in the front surface of the plank. However, it will be appreciated that the key tip need not have a tier, and may have a variety of shapes and configurations, including those described below. Lock 1140 makes an angle 1145 (θ) with a vertical plane. Angle 1135 (θ) ranges in one embodiment from about 85 degrees to 30 degrees, and is preferably about 45 degrees. Angle 1145 preferably is approximately equal to angle 1135.

[0117] A commercially available spindle molder (not shown) is used in one embodiment to machine key 1130 and lock 1140 into siding plank 1100. A spindle molder is similar to woodcutting equipment; however, it is equipped with polycrystalline diamond (PCD) blades for improved performance in cutting FC products. Conventional machining methods for shaping FC material are used to cut the siding plank. The use of low density fiber cement is especially advantageous because it enables easy machining of the material and greater tool life. End surface 1115 is rectangular prior to machining.

[0118] Figure 3 shows a cross-sectional view of siding system 1500. As shown in Figure 3, a first nail 1540 rigidly attaches a first siding plank 1510 to a mounting surface 1560, such that first nail 1540 is completely hidden by the overlap (called "blind nailing"). Mounting surface 1560 is typically a series of wall studs. Key 1130 of first siding plank 1510 is inserted into lock or overlap region 1140 of second siding plank 1520. A second nail 1550 rigidly attaches a second siding plank 1520 to mounting surface 1560. The gap 1530 created between first siding plank 1510 and second siding plank 1520 should be of a size that is aesthetically pleasing. First siding plank 1510 and second siding plank 1520 are substantially identical to siding plank 1100 shown in Figure 1A, Figure 1B, and Figure 2.

[0119] Figure 4 shows a method 1600 of installing siding planks onto a mounting surface to form a siding system, which involves:

[0120] *Mounting first siding plank 1610:* First siding plank 1510 is placed against mounting surface 1560 as shown in Figure 3. First nail 1540 is driven into first siding plank 1510 near its upper edge to rigidly attach it to mounting surface 1560.

[0121] *Aligning lock and key features 1620:* Second siding plank 1520 is placed against mounting surface 1560 above first siding plank 1510 such that lock 1140 of second siding plank 1520 is aligned with key 1130 of first siding plank 1510, as shown in Figure 3.

[0122] *Lowering second siding plank 1630:* Second siding plank 1520 is lowered onto first siding plank 1510. As second siding plank 1520 is lowered (with the help of gravity) onto first siding plank 1510, key 1130 of first siding plank 1510 automatically engages and aligns lock 1140 of second siding plank 1520 into a locked position. In this locked position, key 1130 of first siding plank 1510 prevents second siding plank 1520 from moving under the influence of wind forces, and therefore prevents wind-induced damage. Further, the locked position fixes the gauge and overlap, and creates a uniform shadow line, as shown in Figure 3.

[0123] *Mounting second siding plank 1640:* Second nail 1550 is driven into second siding plank 1520 near its upper edge to rigidly attach it to mounting surface 1560. The method is then repeated to cover the mounting surface to form a larger siding system.

[0124] The embodiment described above has several advantages over the prior art. For instance, it avoids face nailing. Because nails are often used to achieve a tight and uniform fit between two siding planks, it is aesthetically preferable to avoid face nailing because the nail head cannot be hidden when finished. Advantageously, the siding plank assembly of this embodiment provides a way to mate two FC siding planks tightly and creates a uniform shadow line without requiring a face nail to fasten the two siding planks.

[0125] In addition, another advantage is that the embodiment uses gravity during installation to obtain a secure fit between the siding planks. Conventional siding planks such as vinyl offer interlocking features that require an upward motion against the force of gravity to interlock two adjacent siding planks into place. A more natural downward motion, taking advantage of the force of gravity, facilitates installation. Advantageously, the assembly of this embodiment uses gravity to help interlock the planks.

[0126] A further advantage of this embodiment is that it allows the nail or fastener to penetrate directly through the fiber cement plank, in contrast to conventional fiber cement siding planks that are adhered indirectly to a mounting surface. Direct fastening of the fiber cement plank can occur with the fastener penetrating through the plank to attach the plank to the mounting surface.

[0127] Moreover, siding planks in the prior art are often subjected to wind forces that may separate the siding planks from their mounting surface. The embodiment described above reduces the likelihood of damage caused by wind forces.

[0128] The "shadow line" is created by the thickness of a siding plank's bottom edge, which casts a shadow on the siding plank directly below it. A uniform shadow line is aesthetically desirable, and is usually achieved by face nailing the siding planks. The embodiment described above produces a uniform shadow line between two siding planks without requiring a face nail to fasten the siding planks.

[0129] Installers of exterior siding planks balance the desire to install the siding planks quickly against the need to carefully measure the gauge and overlap for consistency. Gauge is the visible vertical

distance between siding planks, and the overlap is the vertical distance that an upper siding plank overhangs a lower siding plank. The key and lock features described above make installation of the siding planks progress more quickly, because the design of the siding planks maintain a consistent gauge and overlap without the need for these properties to be measured.

[0130] It will be appreciated that the lock and key of the siding plank assembly described above is not limited to planks formed of a single piece of material. Thus, as described in further embodiments below, multiple piece siding systems may be used to form the desired aesthetic and functional aspects of the assembly.

II. SIDING PLANKS HAVING AN EXTRUDED FIXING INDICATOR

[0131] In another embodiment, a plank is provided that has a fixing indicator and a fixing void or hollow beneath the fixing indicator. Described herein is a fiber cement product having a fixing indicator and a fixing void or hollow beneath the fixing indicator, and an apparatus for extruding an FC product having a fixing indicator. The result is an FC product that is easy to install and insures proper placement of the fixing device within a predetermined nailing region.

[0132] Figure 5 shows an isometric view of the FC plank of a preferred embodiment. Plank 10100 includes a plank front or outer surface 10110, a fixing indicator 10120 located in proximity to a plank first or upper edge 10130, a plank back or inner surface 10140, and an overlap region or locking region 10150 located in proximity to a plank second or lower edge 10160. Plank 10100 is preferably a siding plank manufactured of FC using a conventional extrusion process. Fixing indicator 10120 is a depression in plank outer surface 10110 formed by an extrusion die as shown in Figure 6. Likewise, overlap region 10150 is a depression in plank inner surface 10140 formed by the extrusion die shown in Figure 6.

[0133] Figure 6 is an end view of extrusion die 10200 of a preferred embodiment. Extrusion die 10200 includes a die outlet 10210 having a die outlet upper surface 10220, a fixing indicator dimple 10230, located in proximity to a die outlet first edge 10240, a die outlet lower surface 10250, and an overlap region form 10260 located in proximity to a die outlet second edge 10270. Extrusion die 10200 is a conventional extrusion die for use with FC mixtures. The opening of die outlet 10210 is shaped to form plank 10100 of Figure 5 as follows:

die outlet upper surface 10220 forms plank outer surface 10110;
fixing indicator dimple 10230 forms fixing indicator 10120;
die outlet first edge 10240 forms plank first edge 10130;
die outlet lower surface 10250 forms plank inner surface 10140;
overlap region form 10260 forms overlap region 10150; and
die outlet second edge 10270 forms plank second edge 10160.

Fixing indicator dimple 10230 has a depth "d," a width "w," and is a distance "a" from die outlet first edge 10240. Preferably, the fixing indicator will comprise an embossed feature between 0.015 and 0.080 inches deep and more preferably between 0.035 and 0.055

inches deep. The indicator can be in the form of a regular or irregular geometric form or a symbol or letter that covers an area of approximately 0.0015 square inches to approximately 0.25 square inches, more preferably between 0.015 square inches and 0.0625 square inches.

[0134] Figure 7 shows a siding plank system of a preferred embodiment. Siding system 10300 includes planks 10100A and 10100B, a wall 10310, and a nail 10320. Using a conventional blind nailing technique, plank assemblies 10100A and 10100B are fixedly connected to wall 10310 using nails (or screws, or staples). Figure 7 shows nail 10320 positioned in fixing indicator 10120 of plank 10100A and driven through plank 10100A into wall 10310. When installed, plank 10100B is positioned such that overlap region 10150 of plank 10100B covers nail 10320 and fixing indicator 10120 of plank 10100A. The first or upper edge 10130 of the plank thus forms a key tip that encases the overlap or locking region 10150.

[0135] It can be seen in Figure 7 that fixing indicator 10120 of a preferred embodiment insures that nail 10320 is not too close to the edge of plank 10100A, thereby preventing cracking or splitting of plank 10100A. Additionally, it can been seen that fixing indicator 10120 insures that nail 10320 is well within overlap region 10150 and is therefore not visible when installed.

[0136] Another embodiment, not shown, is an FC product having a plurality of fixing indicators 10120 in various locations on the outer surface of plank 10100.

[0137] Another embodiment, not shown, is an FC product having a groove on the inner surface of plank 10100 formed by extrusion similar to fixing indicator 10120 and used for gluing plank 10100 to wall 10310 of Figure 7.

[0138] In yet another embodiment, the fixing indicator could be formed using a post-extrusion marking technique, such as using a manual embossing in combination with a conventional Hatschek manufacturing process. Likewise, a manual embossing roller could be used in combination with a conventional extrusion process positioned in proximity to die outlet 10210 of extrusion die 10200 of a preferred embodiment.

[0139] As seen in Figure 8, another embodiment has fixing void 10421 optionally included below the line of the fixing indicator to relieve stress that can lead to break out and cracking of the top edge of the product when nailed or fastened to wall framing or sheathing. The fixing void could be formed using mandrel in the extrusion formation process.

[0140] Figure 8 shows an isometric view of the FC plank of a preferred embodiment. Plank 10400 is another example of an FC plank having a fixing indicator 10420. Plank 10400 shows an example of an aesthetically pleasing pattern on the outer surface of plank 10400 formed by extrusion in similar fashion as fixing indicator 10420 and a fixing void or hollow 10421 below the line of the fixing indicator.

[0141] Advantageously, the siding plank assembly of this embodiment provides an inexpensive affixing indicator on siding planks which reduces damage to the planks at installation due to improper affixing. Furthermore, the installation time of an extruded FC product is also reduced. Additionally, the siding plank

assembly provides an aesthetic appearance as it conceals the affixing by limiting the affixing region to the overlap area between adjacently stacked planks.

[0142] It will be appreciated that the fixing indicator could be formed using post-extrusion marking techniques such as, manual embossing, machining, ink jet or other printing, stamping, pressing, and painting techniques, which are all time-consuming and costly.

[0143] It will further be appreciated that the fixing indicator can be employed in several, if not all, of the siding plank assemblies described herein. For example, like the embodiment of Figures 1-3, the plank of Figure 5 similarly contains a lock in overlap region 10150 and a key tip for insertion into the lock at first edge 10130. Thus, it can be seen that a fixing indicator can be placed similarly on the key 130 of Figure 2.

III. TWO-PIECE FC PLANK AND METHOD OF MAKING THE SAME

[0144] In further embodiments, a two-piece FC plank and a method of making the same are provided. These two-piece planks can be used to form the various shapes described throughout this specification in order to provide a lock and key, hidden nailing, a deep shadow line, and other features described herein. Two methods for forming a two-piece FC plank are described below.

[0145] It will be appreciated that several manufacturing processes for bonding two pieces of FC material together to form a product use standard industry adhesives. However, due to the composition of the FC material and adhesive, the time it takes for the two pieces of FC material to adhere ("adhesion time") is lengthy and the bonding strength of the two FC pieces is weakened. Thus, bonding processes that use standard industry adhesives decrease the durability of installed siding panels and delay the post-processing of the product, which increase the manufacturing cycle time of the product. Advantageously, the bonding process of the below-described embodiments provide a quick process for bonding two FC pieces together to form a durable bond.

A. First Roller Method

[0146] Figures 9A and 9B show isometric views of a two-piece FC plank 2100. Two-piece plank 2100 includes a main plank section 2140, a second piece or butt piece 2130, a first end 2120, and adhesive 2110. Main plank section 2140 is preferably a medium-density FC and is typically about 1/4 inch thick, but may be as thin as about 3/16 inch or less or as thick as about 1/2 inch or more. The width preferably ranges from about 5 to 12 inches, depending on the application. The length preferably ranges between about 12 to 16 feet, depending on the application. Main plank section 2140 may be manufactured with a smooth or textured surface. Further information regarding manufacture of main plank section 2140 may be found in Australian Patent No. AU 515151. Main plank section 2140 has an upper surface 2140U, also considered to be the back surface.

[0147] Butt piece 2130 is preferably made from a medium-density FC material, and is typically about 5/16 inch thick, but may be as thin as about 1/4 inch or less, or as thick as about 5/8 inch or more. The width of butt piece 2130 is typically about 1 1/2 inch, but may be as wide as about 2 inches or more, or as

narrow as about 5/8 inch or less, depending on the application. The length is typically the same as main plank section 2140 (about 12 to 16 feet), depending on the application. Butt piece 230 has a lower surface 2130L, also considered the front surface. The function of butt piece 2130 is to reinforce main plank section 2140, thereby increasing the overall rigidity of plank 2100. A second function of butt piece 2130 is to provide thickness for an improved shadow line, a desired aesthetic quality.

[0148] Adhesive 2110, located between upper surface 2140U of main plank section 2140 and lower surface 2130L of butt piece 2130, in one embodiment is a fast setting, reactive hot-melt polyurethane with a viscosity of about 10,000 to 100,000 CPS at application temperatures. Other embodiments for the adhesive 2110 are described below. The application temperature for adhesive 2110 ranges from about 200° to 325°F. The adhesion time ranges from about 3 to 5 seconds. The adhesion time is the time taken for the bond strength to develop after the adhesive is applied and nip pressing is performed.

[0149] In operation, adhesive 2110 is applied in beads on upper surface 2140U of main plank section 2140 along its length. This may be accomplished by using a Nordson hot-melt extrusion system. The adhesive beads are preferably spaced apart by a small distance, such as about 1" or 1/2". The preferred amount of adhesive is about 1 gram/foot/bead, though the amount may be as small as about 0.5 grams/foot/bead or as large as about 2 grams/foot/bead. Immediately upon applying adhesive 2110 (e.g., within about 3 seconds), lower surface 2130L of butt piece 2130 is interfaced with upper surface 2140U of main plank section 2140 such that first end 2120 of butt piece 2130 faces the center of main plank section 2140 as shown in Figure 9A. The arrangement of main plank section 2140 and butt piece 2130 forms two-piece plank 2100 having an upper surface 2100U and a lower surface 2100L. Preferably the bottom surfaces of the main plank section 2140 and the butt piece 2130 are preferably flush.

[0150] As shown in Figure 10, first end 2120 of butt piece 2130 makes an angle theta θ of about 15 degrees, but may range from about 0 degrees to 60 degrees, with the horizontal plane. The function of the angled surface is to aid water drainage.

[0151] Figures 11A and 11B show isometric and end views, respectively, of a pressure roller system 2200 for squeezing main plank section 2140 to butt end 2130. System 2200 includes a first roller 2210, and a second roller 2220.

[0152] First roller 2210 and second roller 2220 are preferably opposing 7-inch diameter steel rollers and are arranged parallel to and adjacent one another with a gap in between. In operation, plank 2100 is fed through the gap between first roller 2210 and second roller 2220. The gap between roller 2210 and 2220 is sized to engage plank 2100 with an interference fit. Thus, first roller 2210 is in direct contact with upper surface 2100U of butt piece 2130, and second roller 2220 is in direct contact with lower surface 2100L of plank 2140. Plank 2100 is transported through roller system 2200 at approximately 50 feet/minute. As plank 2100 transverses through roller system 2200, first roller 2210 and second roller 2220 compress plank 2100 at a pressure of approximately 750 lb/inch of roller width for approximately 3 to 5 seconds.

[0153] Figure 12 describes a method 2400 for making a two-piece medium density plank 2100, which involves:

[0154] *Melting adhesive 2410:* Fast-setting, reactive hot-melt polyurethane is melted in a hot-melt application system. One such system is commercially available from Nordson Corporation. Application temperatures range from about 200° to 325°F.

[0155] *Are the plank and butt piece flat? 2420:* The plank 2140 and butt piece 2130 are viewed for flatness. If plank 2140 and butt piece 2130 are determined to be flat, the process is continued to step 2430. If plank 2140 and butt piece 2130 are determined to be wavy or uneven, refer to method 2500, as shown in Figure 13.

[0156] *Applying adhesive 2430:* Typically about 1 gram/foot/bead, but may be as small as about 0.5 g or as large as about 2 g, of hot-melt adhesive is applied in beads spaced about ½" to 1" apart on upper surface 2140U of main plank section 2140 (see Figure 9A) using the Nordson Corporation system extrusion nozzle.

[0157] *Placing butt-piece on adhesive 2440:* Butt-piece 2130 is placed onto adhesive 2110, shown in Figure 9A and as described above.

[0158] *Maintaining pieces under pressure 2450:* Immediately (preferably within 3 seconds) upon completion of step 2440, plank 2100 is passed through roller system 2200, which maintains the plank under pressure (about 750 lb/inch of roller width) preferably for a minimum of 3 seconds to allow adhesive 2110 time to cool and bond with main plank section 2140 and butt piece 2130. The squeezing of main plank section 2140 and butt end 2130 causes the beads of adhesive 2110 to spread out in a thin layer.

[0159] The method, shown in Figure 12, is a process for maintaining pressure on plank 2100 when plank 2140 and butt piece 2130 are both flat. However, a further process was developed to bond surfaces that have variable flatness, shown in Figure 13.

[0160] Figure 13 describes another method 2500 for a making two-piece medium density plank 2100, which involve:

[0161] *Melting adhesive 2510:* Fast-setting, reactive hot-melt polyurethane is melted in a hot-melt application system. One such system is commercially available from Nordson Corporation. Application temperature of typically about 250°, but may range from about 200° to 325°F.

[0162] *Are the plank and butt piece flat? 2520:* The plank 2140 and butt piece 2130 are viewed for flatness. If plank 2140 and butt piece 2130 are determined to be flat, refer to method 2400, shown in Figure 12. If plank 2140 and butt piece 2130 are determined to be wavy or uneven, continue process to step 2530.

[0163] *Applying adhesive 2530:* Typically about 1 gram/foot/bead, but may be as small as about 0.5 g or as large as about 2 g, of hot-melt adhesive is applied in beads spaced about ½" to 1" apart (a minimum of 2 beads are preferably applied) on upper surface 2140U of main plank section 2140 (see Figure 9A) using the Nordson Corporation system extrusion nozzle.

[0164] *Placing butt-piece on adhesive 2540:* Butt-piece 2130 is placed onto adhesive 2110, shown in Figure 9A and as described above.

[0165] *Maintaining pieces under pressure 2550:* Immediately (preferably within about 9 to 12 seconds) upon completion of step 2540, plank 2100 is placed in a conventional hydraulic plate press or continuous press (not shown), which maintains the plank 2100 under pressure (about 750 psi) for a minimum of about 4 seconds to allow adhesive 2110 time to cool and bond with main plank section 2140 and butt piece 2130. The squeezing of main plank section 2140 and butt end 2130 causes the beads of adhesive 2110 to spread out in a thin layer.

[0166] Advantageously, the two-pieces of FC material can be bonded quickly so that post-bonding processes can be initiated immediately. Furthermore, bonding two FC material members together is more cost-effective than machining a single rectangular FC section to form the equivalent structure. The siding plank assembly creates an enhanced shadow line by virtue of the first end of the butt end extending partially over the upper surface of the main plank section and provides a traditional cedar look with a thick butt edge. The butt end piece also results in increased rigidity of the FC panel product so that it can be easily handled and installed.

[0167] It will be appreciated that although the shapes described herein are formed from two pieces of fiber cement, an equivalent shape can be formed by machining a solid rectangular section. However, this method may be more costly and produce a high amount of waste material. It will also be appreciated that additional shapes can be produced, such as described below, by abutting the two pieces together.

B. Second Roller Method

[0168] In another embodiment, a cementitious adhesive mixture, described below, is located between upper surface 2140U of plank 2140 and lower surface 2130L of butt piece 2130, as shown in Figures 9A and 9B. In operation, adhesive is applied to either upper surface 2140U of plank 2140 or lower surface 2130L of butt piece 2130 along its length. The thickness of applied adhesive 2110 is dependant upon the uniformity of textured surfaces 2130L and 2140U, typically in an amount that covers surfaces 2130L or 2140U, but preferably does not exceed about 1/8 inch.

[0169] As an alternative to the roller system described above, Figures 14A and 14B show plank assembly 3100, and include a hand roller 3210 and an interleaver 3150. Interleaver 3150 is a cured FC material used to support plank assembly and is in physical contact with lower surface 3140L of the plank. In operation, hand roller 3210 is in functional contact with upper surface 3130U of butt piece 3130. Hand roller 3210 is rolled along the length of plank assembly and is used to apply pressure to upper surface 3130U of butt piece 3130 while adhesive 3110 bonds plank 3140 and butt piece 3130 together.

[0170] Figure 15 illustrates the process for making a two-piece medium density plank assembly with the cementitious adhesive, described below. The method involves:

[0171] *Applying adhesive 3310:* Adhesive 3110 is applied to upper surface 3140U of plank 3140, shown in Figure 14A, 14B.

[0172] *Interfacing butt piece with plank 3320:* Lower surface 3130L of butt-piece 3130 is interfaced with upper surface 3140U of plank 3140, shown in Figure 14A and 14B

[0173] *Applying pressure to butt piece 3330:* Hand roller 3210 is rolled over the length of surface 3130U of plank assembly 3100 in a direction normal to the upper 3130U and lower 3140L surfaces, shown in Figures 14A and 14B, to force contact of adhesive with fiber cement pieces, and provide adhesion between butt piece 3130 and plank 3140.

[0174] *Pre-curing adhesive 3340:* Plank assembly is air dried typically for about 12 hours, but may be as long as about 24 hours or more, or as short as about 8 hours or less.

[0175] *Autoclaving plank assembly 3350:* Plank assembly is autoclaved at a temperature between about 350° to 400°F at about 120 to 145 psi for a period of approximately 8 hours.

[0176] *Trimming Plank Assembly 3360:* Overflow of cementitious adhesive 3110 is trimmed from cured and autoclaved plank assembly.

[0177] The use of a cementitious adhesive as described below to adhere the two pieces of fiber cement together has all of the advantages described above for the polymeric adhesive. Another advantage is that a cementitious adhesive is compatible with fiber cement materials, is economical and can be co-cured with the fiber cement pieces to form a durable bond.

C. Cementitious Adhesive Composition

[0178] The embodiments described above for adhering two pieces of fiber cement plank together in one preferred embodiment utilize a novel cementitious adhesive composition. Thus, one aspect of the present invention provides a composition of matter for, and method of making a cementitious adhesive for bonding materials, preferably FC materials, and more preferably medium density FC materials. The adhesive ingredients preferably include cement, silica, thickener, and water, and may include organic fibers or inorganic fibers. The adhesive formulation can be used to bond FC materials prior to autoclaving.

[0179] It will be appreciated that a preferred adhesive is able to withstand autoclave temperatures and is compatible with FC materials. Most conventional polymeric adhesives and polymer-modified adhesives melt, burn, or degrade when exposed to temperatures in excess of approximately 375 degrees F. During the manufacturing process, FC materials are dried in an autoclave that can reach approximately 400 degrees F. Therefore, conventional polymeric adhesives cannot be used to bond FC materials prior to autoclaving.

[0180] Moreover, a preferred adhesive selected for use on FC materials should be compatible and as similar in composition as possible to the materials being bonded. This ensures that the system as a whole will respond to environmental factors in a similar manner within each component (environmental factors include temperature fluctuations, acid rain impacts, humidity, and wet-dry cycles). The adhesive and the FC materials will age similarly and thus will not weaken the system.

[0181] Advantageously, the adhesive composition of this embodiment can withstand curing temperatures in an autoclave and is compatible with the FC material to be bonded. Furthermore, the adhesive composition is less costly, more readily available, and more environmentally friendly compared with polymeric or polymer-modified adhesives. Unlike other adhesives, the adhesive composition also does not degrade under alkaline or moist conditions.

[0182] The cement, silica, and thickener are all added to the adhesive mix in powdered form, where the particle size for each ingredient may measure up to about 200 microns. The cement may be present in the formulation in an amount between about 10 and 90 wt %, the silica may be present in the formulation in an amount up to about 90 wt %, and the thickener may be present in the formulation in an amount up to about 2 wt %. Water may be present in the formulation in an amount up to about 90 wt %. (All references to weight in this document are provided on a dry material weight basis, unless otherwise indicated.)

[0183] The organic fiber in the formulation may be in the form of cellulose fiber (where the fiber may be bleached pulp), and may be present in the formulation in an amount up to about 5 wt %. The inorganic fiber in the formulation may be in the form of Wollastonite, and may be present in the formulation in an amount up to about 30 wt %. Both forms of fiber (organic and inorganic) may measure up to about 3 mm in length.

Table 2. Exemplifying formulations of cementitious adhesive.

Raw Materials	*Percent Raw Material by Dry Weight*		
	Formulation 1	Formulation 2	Formulation 3
Organic fiber (e.g. bleached pulp)	0.5%	0%	0%
Cement	59.5%	59.7%	47.7%
Silica	39.5%	39.8%	31.8%
Inorganic fiber (e.g. Wollastonite)	0%	0%	20%
Thickener	0.5%	0.5%	0.5%
Water	430 to 470 milliliters of water per Kg of dry solids		

[0184] Table 2 shows three exemplifying formulations of cementitious adhesive. Each formulation contains cement to form the body of the bond, and fine-ground silica to react and bind with cement when autoclaved. The silica also acts as a filler/aggregate that lowers the cost of the matrix, without significantly reducing performance. Thickener slows the water being drawn from the slurry (adhesive) into the fiber cement. The presence of thickener ensures that the cementitious adhesive remains "tacky" during the bonding process of the fiber cement surfaces, ensures that the adhesive fills the gap between the pieces to be bonded, and "wets out" the second surface, which is necessary to develop a good cementitious bond. The thickener also slows/reduces settling in the slurry and prolongs "open time" to add viscosity to the wet adhesive.

[0185] Formulation 1 and Formulation 3 additionally contain fiber to increase the bond strength. Both organic and inorganic fibers perform similarly in the formulation; however, organic fiber requires

preparation for use, and inorganic fiber tends to be more costly to purchase than organic fiber. Although fiber adds strength to the adhesive formulation, it can also clog some applicators during use. To address this issue, Formulation 2 contains no fiber. Water is added as a necessary reactant for the cement in forming the hydrated cementitious bond. Water also provides the mixture "viscosity" necessary to mix the adhesive, to disperse fibers and solids through the mixture, and to apply the adhesive.

[0186] Figure 16 shows a method 4100 of making cementitious adhesive for bonding medium-density FC materials that includes:

[0187] *Step 4110: Does adhesive formula contain fiber?* In this step, method 4100 proceeds to step 4112 if the formulation being made contains fibers. Otherwise, method 4100 proceeds to step 4115.

[0188] *Step 4112: Does adhesive formula contain organic fiber?* In this step, method 4100 proceeds to step 4130 if the formulation being made contains organic fibers. Otherwise, the formulation is presumed to contain inorganic fibers and method 4100 proceeds to step 4120.

[0189] *Step 4115: Mixing silica, cement and water.* In this step, method 4100 adds the powdered silica to water to produce a 50 wt % silica slurry, and then transfers the silica slurry to a mixer (such as a Hobart mixer). Method 4100 adds powdered cement and water to bring the percent by weight of solids to approximately about 68% to 70% (approximately about 430 to 470 milliliters total water per kilogram of solids), and then mixes the adhesive formulation for about five minutes to attain homogeneity in the mixture. An example of a Hobart mixer is shown in Figure 17. Method 4100 then proceeds to step 4140. Figure 17 is a schematic of Hobart style low shear mixer 4200 containing an adhesive formulation. Both views A and B include a Hobart mixing bowl 4210 and an adhesive formulation 4240. In view A, a ribbon blade 4220 blends adhesive formulation 4240, and in alternate view B, a whisk blade 4230 blends adhesive formulation 4240. Either blade may be used to obtain similar results.

[0190] *Step 4120: Mixing silica, inorganic fiber, cement, and water.* In this step, method 4100 adds the powdered silica to water to produce a 50 wt % silica slurry, and then transfers the silica slurry to a mixer (such as a Hobart mixer, shown in Figure 17). Method 4100 adds the powdered cement and water, adds extra water to bring the percent by weight of solids to approximately 67% to 68% (approximately 470 to 500 milliliters total water per kilogram of solids), and mixes the adhesive formulation for about five minutes. Method 4100 then proceeds to step 4140.

[0191] *Step 4130: Dispersing organic fiber in water.* In this step, method 4100 adds the organic fiber, such as unbleached or bleached pulp. The pulp is previously hydropulped, refined, and diluted with water to about 0.4% by weight. Method 4100 mixes and disperses the organic fiber for approximately five minutes.

[0192] *Step 4132: Mixing silica and cement.* In this step, method 4100 adds the silica and then the cement to the organic fiber, and mixes the mixture. The preferable approach is to mix the ingredients of silica, cement, and fiber, then to blend the ingredients for five minutes in a mixer (such as a Hobart mixer, shown in Figure 17) to attain homogeneity in the mixture.

[0193] *Step 4134: Dewatering mix (optional).* Following step 4132, a dewatering apparatus 4300, shown in Figure 18, dewaters the mix to achieve a thin paint consistency as described below. Method 4100 then proceeds to step 4140.

[0194] Figure 18 is a schematic of a dewatering apparatus 4300, which includes a first side 4310, a second side 4320, a third side 4330, and a fourth side 4340. In one embodiment, each side of dewatering apparatus 4300 preferably has identical length, width, and height. In another embodiment, each side would measure approximately ten inches long and three inches high. The sides are arranged such that first side 4310 and third side 4330 are parallel to each other, second side 4320 and fourth side 4340 are parallel to each other, and each side is joined to two other sides at 90 degree angles (e.g., first side 4310 is arranged at a 90 degree angle to second side 4320 and fourth side 4340), as shown in Figure 18.

[0195] Dewatering apparatus 4300 is designed to hold a perforated metal plate 4316, a coarse mesh screen 4314 and a fine mesh screen 4312. Views A, B, and C in Figure 18 show plan views of screens 4312 and 4314, and plate 4316, respectively. Fine mesh screen 4312 conforms to ASTM#325; coarse mesh screen 4314 conforms to ASTM#10; and plate 4316 is approximately 3/16" thick, and is perforated with round ¼" diameter holes 4317, at a frequency of 9 holes per square inch. Screens 4312 and 4314, and plate 4316 may be made of metal or other comparable materials to provide similar functionality.

[0196] In operation, the adhesive formulation is poured into dewatering apparatus 4300. A set of mesh screens and a metal plate (not shown) identical to 4312, 4314, and 4316 are stacked in reverse order on top of the set inside 4300 so that the screens and plates are parallel to each other, and the adhesive formulation is contained between the two sets. Downward pressure applied to the screens and plates dewaters the adhesive formulation. Water either exits through the bottom of dewatering apparatus 4300 or a vacuum apparatus (not shown) may optionally be used to remove pooled liquid from the top of the screens and plates.

[0197] *Step 4140: Transferring to high shear mixer.* In this step, the adhesive formulation 4240 is added to a high shear mixer, as shown in Figure 19. Figure 19 shows a high shear mixer 4400 containing an adhesive formulation 4240. The adhesive formulation 4240 is added to a high shear mixing bowl 4410, where a high shear mixing blade 4420 revolves at a speed sufficient to create a vortex in the center of the mixing bowl (approximately 6000 RPM) and completely integrate all ingredients.

[0198] *Step 4142:* Adding *thickener.* In this step, method 4100 adds thickener to high shear mixer 4400 as required to achieve a thick paint consistency. Thickeners may be made of commercially available cellulose derivatives, polyurethane and polyacrylate, such as "Bermocell" (cellulose ether), "Ethocel" (ethyl cellulose polymer), "Cellosize" (hydroxy ethyl cellulose), or "Natrosol" (hydroxyl ethyl cellulose and derivatives). One preferred thickener is "Natrosol Plus D430", a cellulosic derivative (hydrophobically modified hydroxy ethyl cellulose). The amount of thickener in one embodiment is nominally 0.5 wt %; however, more may be added to achieve the desired viscosity. A visual determination is sufficient to ascertain desired viscosity of the adhesive formulation.

[0199] It will be appreciated that other adhesives may be used to bond the FC materials. These include polymers or polymer-modified adhesives (called "thin-sets") to bond the FC materials. However, these products may not be suited for exposure to high temperatures in an autoclave. Plastics degrade at approximately 375 degrees F and break down during autoclaving. In addition, the polymers and polymer-modified adhesives are more costly to use compared with the preferred adhesives described above.

IV. VARIOUS DESIGNS OF TWO-PIECE FC PLANKS

[0200] The one and two-piece FC planks described above advantageously enable the formation of a variety of different shapes that provide a variety of desired features to the plank. Various designs are described below with respect to two-piece planks. However, it will be appreciated that similar shapes can be formed using one piece of material or other combinations of materials, such as described below.

A. Two-Piece Medium Density Plank with Locking Feature and Method of Making the Same

[0201] In one embodiment, a two-piece FC plank includes a butt piece having a lock such as described above. As shown in Figure 20A and Figure 20B, plank assembly 5100 includes a plank 5140, a butt piece 5130, and adhesive 5110. In this embodiment, plank 5140 further includes a key 5160, and butt piece 5130 further includes a lock 5150.

[0202] Figure 21 shows a side view of plank assembly 5100. As shown in Figure 21, lock 5150 makes a lock angle 5285 with respect to horizontal line 5290. Lock angle 5285 in one embodiment ranges from approximately 5 degrees to 60 degrees, more specifically about 45 degrees is preferred. Key 5160 makes an angle of key angle 5275 in one embodiment with respect to horizontal line 5280. Key angle 5275 ranges from approximately 5 degrees to 60 degrees, more specifically about 45 degrees is preferred, but in any case substantially equal to lock angle 5285. Methods of cutting lock 5150 and key 5160 (e.g. using saw blades, high speed molders, abrasive grinding tools, or a router fitted with cutting tools for FC materials) are well known in the art.

[0203] Figure 22 shows a cross-sectional view of two installed plank assemblies. As shown in Figure 22, a first nail 5340 rigidly attaches a first plank assembly 5300 to a mounting surface 5360. Mounting surface 5360 is typically a wall stud. A second nail 5350 rigidly attaches a second plank assembly 5310 to mounting surface 5360. First plank assembly 5300 and second plank assembly 5310 are substantially identical to plank assembly 5100 previously described. First plank assembly 5300 includes key 5320, which is inserted into lock 5330 of second plank assembly 5310.

[0204] Figure 23 shows a method of installing plank assemblies onto a mounting surface, including the following steps:

[0205] *Step 5410:* Mounting *first plank assembly*. In this step, first plank assembly 5300 is placed against mounting surface 5360 as shown in Figure 22. First nail 5340 is driven into first plank assembly 5300 to rigidly attach it to mounting surface 5360.

[0206] *Step 5420:* Aligning *lock and key features.* In this step, second plank assembly 5310 is placed against mounting surface 5360 above first plank assembly 5300 such that lock 5330 of second plank assembly 5310 is aligned with key 5320 of first plank assembly 5300, as shown in Figure 22.

[0207] *Step 5430: Lowering second plank assembly.* In this step, second plank assembly 5310 is lowered onto first plank assembly 5300. As plank assembly 5310 is lowered (with the help of gravity) onto first plank assembly 5300, key 5320 of first plank assembly 5300 automatically engages and aligns lock 5330 of second plank assembly 5310 into a locked position. In this locked position, key 5320 of first plank assembly 5300 prevents second plank assembly 5310 from moving under the influence of wind forces, and therefore prevents wind-induced damage.

[0208] *Step 5440: Mounting second plank assembly.* In this step, second nail 5350 is driven into second plank assembly 5310 to rigidly attach it to mounting surface 5360.

[0209] Advantageously, the siding plank assembly of this assembly can be used to mate two siding planks tightly and uniformly without requiring a visible nail fastening the overlapping region of the two planks to resist high wind loads. Furthermore, the siding plank assembly requires no starter strip at the base of the wall to provide the lap plank angle of the first installed plank. The lock and key also set the horizontal gauge of the exposed plank face without requiring frequent measuring.

[0210] It will be appreciated that another way to prevent wind forces from damaging planks is to nail the butt piece down. However, this method is time extensive, may cause breaks or splits in the FC material, and reduces the aesthetic appeal of the installed plank.

B. <u>Plank Having Oversized "V" Style Lock and Compressible Regions, and Method of Making Same</u>

[0211] In another embodiment, a two-piece FC plank utilizes an oversized "V" style lock system and added compressible material to provide added ease of installation and aesthetic value. This embodiment also applies to any plank of similar shape that uses a locking mechanism in place of face nailing an outer plank bottom edge to an inner plank top edge, where the inner plank top edge has been nailed to a frame. The "V" style lock allows planks to be locked into one another without requiring extensive measurement to maintain gauge (the visible vertical distance between planks) and overlap (the vertical distance the plank overhangs the plank below) during installation.

[0212] The design described below is particularly advantageous for walls that are not completely planar. When installing exterior siding, it is common to encounter walls that are not completely planar. For example, wood studs within a wall may bow when the wood dries after installation and create a non-planar or "wavy" wall. This presents both installation problems and finishing issues. If a "V" style FC plank does not lock completely (such that both planks being locked are flat against the wall), the gauge and overlap vary across the wall. As a result of being poorly fitted, the plank may subsequently experience lateral movement (flapping) when subjected to wind.

[0213] Advantageously, the planks described herein are more easily installed on non-planar walls because they can fit together without excessive force. Furthermore, the lock and key design will maintain gauge and overlap better than other "V" style lock designs. As such, the planks will look better on the wall because they will be straighter than the frame, which is often non-planar.

[0214] Figure 24 shows an isometric view of a FC plank assembly 6100, which includes a plank body 6105, a lock assembly 6150, and an adhesive 6115. Plank body 6105 is fixedly connected to lock assembly 6150 via an adhesive layer 6115, as shown in Figure 24. Adhesive 6115 is preferably a polymeric hot-melt adhesive or a cementitious adhesive. The method of making a two-piece plank bonded with one of these two adhesives is described above. Table 3 shows preferred ranges of plank body 6105 dimensions for one embodiment:

Table 3. Preferred range of plank dimensions

Dimension	Range/Units
Thickness	about 3/16-1/2 inch
Width	about 5-12 inches
Length	about 12-16 feet

[0215] Figure 25 shows a cross-section of plank assembly 6100 taken along line 25-25 shown in Figure 24. This view shows how lock front surface 6370 is bonded to plank back surface 6120 via adhesive 6115. The method used to bond lock front surface 6370 to plank back surface 6120 is the same as that described above. Figure 26 shows a key 6200, part of plank assembly 6100, in greater detail. Key 6200 includes key tip 6210, which is a surface cut on a horizontal plane, parallel to horizontal line 6212, to "blunt" the edge between plank front surface 6215 and plank top surface 6110. The length of key tip 6210 is X_k, as shown in Figure 26. Length X_k may vary in one embodiment from about 1/16" to 3/16". Plank top surface 6110 is cut at an angle θ, relative to horizontal line 6212, which may range from about 5 degrees to 60 degrees.

[0216] Figure 27 shows the lock assembly 6150 in greater detail, including a lock inner angled surface 6315, where first compressible region 6310 is located, a lock inner surface 6325, where second compressible region 6320 is located, and a lock inner blunted surface 6330. The length of lock inner blunted surface 6330 is X_l, as shown in Figure 27. Length X_l may range from about X_k + 1/16" to X_k + 1/8." First compressible region 6310 and second compressible region 6320 may be constructed of compressible materials, such as polyurethane elastomeric foam, rubber, rubber foam, or silicone rubber.

[0217] Again in reference to Figure 27, lock inner blunted surface 6330 is shown at an about 90-degree angle to lock front surface 6370. The purpose of "blunting" the sharp cut where lock inner surface 6325 and lock inner angled surface 6315 meet is to provide a substantially flat surface rather than a sliding point for the plank assembly to be locked into the plank assembly above. Lock inner blunted surface 6330 provides a more positive gauge for the plank assembly.

[0218] Figure 28 shows the approximate dimensions of lock assembly 6150. Preferred ranges for the labeled dimensions in Figure 27 and Figure 28 are shown below in Table 4.

Table 4. Preferred range of variables for lock assembly dimensions as shown in Figures 27 through 29

Dimension as Labeled in Figure 28 and Figure 29	Range of Dimension
A	about 3/16" to ½"
B	about 3/16 to ½"
C	about 0" to 1 ¼"
D	about ½" to 2.0"
H	about ½" to 2.0"
W	about 3/8" to ¾"
X_k (key)	about 1/16" to 3/16"
X_l (lock)	about X_k + 1/16" to X_k + 1/8"
Y	about 1/32" to 1/8"
α (alpha)	about 0 degrees to 60 degrees
β (beta)	about 0 degrees to 30 degrees
γ (delta)	about 30 to 85 degrees
δ (gamma)	about 30 to 85 degrees

[0219] Figure 29 illustrates how key 6200 of a first plank assembly 6510 fits into lock assembly 6150 of a second plank assembly 6520, and how the shape of lock assembly 6150 and key 6200 enhance the performance of the plank assembly. Lock inner blunted surface 6330 and key tip 6210 are each cut at 90-degree angles to plank front surface 6215. This design allows the plank assemblies some lateral compensation for installation on non-planar walls. Although lock assembly 6150 may shift laterally after being installed, the overlap is maintained because key tip 6210 and blunted surface 6330 do not shift vertically. First compressible region 6310 and second compressible region 6320 have been added to the embodiment to seal lock assembly 6150 with key 6200, and to absorb lateral movement of plank assembly 6510 and 6520. The existence of compressible regions 6310 and 6320 also increases the ease of installation because the plank assemblies can be locked into place without requiring excessive force. The second plank assembly 6520 locked into the first plank assembly 6510 below it can move within the compressible distance between lock inner angled surface 6315 and the top of first compressible region 6310, and between lock inner surface 6325 and the top of second compressible region 6320.

[0220] Because the wall frame is often not "plumb" (the wall may be non-planar), the top surface of key 6200 does not form a straight line. By allowing the bottom surface of second plank assembly 6520 to move relative to the key 6200, the lock assembly 6150 can still be straight when placed over the key 6200 (it is being held straight by its own stiffness). Although not perfect, the arrangement is a considerable improvement in the waviness of the wall compared with just following the faults in the frame.

[0221] Figure 30 shows how a siding system 6400 appears after installation on a mounting surface 6410. Mounting surface 6410 is typically made of a series of wall studs (not shown). Plank assemblies 6400A, 6400B, 6400C, and 6400D are installed such that each plank assembly locks into the plank assembly below it. For example, nail 6420A fixes the top of plank assembly 6400A to mounting surface 6410. Plank

assembly 6400B is installed directly above it, such that the oversized "V" style lock secures plank assembly 6400B. Nail 6420B then fixes the top of plank assembly 6400B to mounting surface 6410. This process is repeated with plank assembly 6400C, plank assembly 6400D, nail 6420C, and any additional plank assemblies and nails required to cover the mounting surface as desired.

[0222] The lock and key design, combined with compressible regions 6310 and 6320, provide some "give" (lateral compensation) in siding system 6400. As a result, the siding will compensate for moderate non-planarity of mounting surface 6410 and siding system 6400 will appear planar (flat).

[0223] Figure 31 shows a flow chart of a method 6500 of making a two-piece FC plank with an oversized "V" style lock and compressible regions, including the steps of:

[0224] *Step 6510: Manufacturing plank.* In this step, a plank is preferably manufactured according to conventional Hatschek methods.

[0225] *Step 6520: Bonding plank pieces.* In this step, plank body 6105 is bonded to lock assembly 6150 to form the plank assembly 6100 shown in Figure 24. The method of bonding two pieces of FC material to form a two-piece plank either using a polymeric hot-melt adhesive or a cementitious adhesive is described above in greater detail. Some alternate embodiments may not require this step if they do not include bonded pieces.

[0226] *Step 6530: Machining plank to form key and lock.* In this step, planks are fabricated and machined to the requisite shape. In reference to Figures 24-26, plank body 6105 is cut to form the plank top surface 6110 and plank bottom surface 6130. Specifically, plank top surface 6110 is cut (to form the key) at an angle of θ, which ranges from about 5 degrees to 60 degrees, as shown in Figure 26. Plank bottom surface 6130 is cut at an angle of β, which ranges from about 0 to 30 degrees, as shown in Figure 27. To form the lock assembly 6150, the bonded piece is first cut at angle beta to form lock bottom surface 6360, as shown in Figure 27. The remaining surfaces of lock assembly 6150 are cut to meet the specifications of length and angle listed in Table 4 above. Moreover, this step uses the same method as described above in making a two-piece plank with a lock and key design, including steps required to cut the plank.

[0227] *Step 6540: Attaching compressible regions.* In this step, first compressible region 6310 and second compressible region 6320 are attached to lock assembly 6150. Materials that may be used for compressible regions 6310 and 6320 include commercially available products such as polyurethane elastomeric foam, rubber, rubber foam, and silicone rubber. The compressible regions are applied using conventional application methods, such as "Nordsons" FoamMelt (R) application equipment such as the Series 130, applied at about 250 degrees F to 350 degrees F. First compressible region 6310 is applied to the length of the lock assembly 6150 along lock inner angled surface 6315, and second compressible region 6320 is applied to the length of lock assembly 6150 along lock inner surface 6325, as shown in Figure 27. The thickness y of compressible region 6310 and compressible region 6320, as shown in Table 4, may range from about 1/32" to 1/8".

[0228] This particular embodiment describes a two-piece plank; however, the use of compressible regions may be applied to other plank designs as well. Some examples of planks that could utilize this feature are any of the above-described one or two piece planks and the below-described plank having a plastic spline. An extruded plank could utilize this feature, as could any plank of similar shape that uses a locking mechanism in place of face nailing an outer plank bottom edge to an inner plank top edge, where the inner plank top edge has been nailed to a frame. Exemplifying diagrams of two plank designs that could utilize the compressible regions are shown in Figure 32.

[0229] Figure 32A and 32B show plank designs that could utilize compressible regions to enhance the plank functionality. Figure 32A shows extruded plank 6810 with first compressible region 6812A and second compressible region 6814A. Figure 32B shows hollow plank 6820 with first hollow region 6815 and second hollow region 6817, where the hollow regions may be filled with foam or other material, or left open with no fill, and also shows first compressible region 6812B and second compressible region 6814B.

[0230] The design described above advantageously allows planks to be more easily installed on non-planar walls because they can be fit together without excessive force. The compressible material also advantageously forms a capillary break, such as described below. Furthermore, the compressible material acts as a seal against wind and rain.

V. TWO-PIECE PLANK HAVING A PLASTIC SPLINE

[0231] In additional embodiments, a plastic spline having a butt and lock is provided, which is designed for use in combination with a FC plank for a siding application. The result is a two-piece FC plank assembly having an FC siding plank bonded with an adhesive to a plastic spline having a butt and lock.

[0232] Advantageously, the siding assembly of these embodiments provide a lightweight siding assembly having a reduced amount of the FC material while maintaining an aesthetically pleasing shadow line when installed. They also provide for a low-cost siding assembly with increased stiffness and strength, which reduces breakage and improves handleability and ease of installation. The siding assembly is also suitable for blind nailing and capable of high wind loads. The spline can also be easily manufactured from plastic with fine details using an extrusion and or molding processes well known in the art. The term plastic includes, but is not limited to, polymeric resins, copolymers and blends thereof with suitable flexural and tensile strength for the anticipated use and a heat deflection point well above the maximum normally experienced in the building environment (approximately 40°C to 60° C). Such plastics could include but are not limited to: polystyrene, polyvinyl chloride, polyolefin, polyamide (nylon), and ABS. These plastics can contain mineral fillers to reduce cost or weight and improve strength or toughness properties. Alternatively, these plastics may also contain fibers to improve tensile strength. The plastic spline can be manufactured using low grade or recycled plastic for additional cost savings without sacrificing desired attributes.

A. Spline with Angled Lock

[0233] Figure 33 shows an isometric view of the siding plank assembly of one preferred embodiment. Plank assembly 7400 includes a plank 7100 and a spline 7200. Plank 7100 is preferably a

siding plank manufactured of medium-density FC material using a well-known Hatschek process. Spline 7200 is a "butt and lock" type spline manufactured of rigid plastic using a well-known extrusion process. Spline 7200 is aligned and is fixedly connected with an adhesive to plank 7100 (described in greater detail below).

[0234] Figure 34 shows an isometric view of the FC siding plank of a preferred embodiment. Plank 7100 is a siding plank that includes a plank top surface 7105, and a plank back surface 7120. Plank 7100 has a length "l", a width "w", a height "h", and a flat "t". An example of plank 7100 dimensions include "l" between about 12 and 16 feet, "w" between about 3/16 and 1/2 inches, "h" between about 5 and 12 inches, and "t" between about 0 and 1/4 inches. A cross-sectional diagram of plank 7100 is shown in Figure 35.

[0235] Figure 35 is a cross-sectional diagram of plank 7100 taken along line 35-35 of Figure 34. In this view, additional details of the plank 7100 are visible. Plank 7100 further includes a plank bottom surface 7110 and a plank front surface 7115. Also shown are plank top surface 7105 and plank back surface 7120. Plank top surface 7105 is set at an angle "α" to plank front surface 7115. Plank bottom surface 7110 is set at an angle "β" to plank front surface 7115. In one example, "α" is 45° and "β" is 84°. Angles "α" and "β" of plank 7100 are cut using angled water jet cutters during normal Hatschek manufacturing processing. Preferred dimensions and angles of plank 7100 are indicated in Table 5.

Table 5: Plank 7100 dimensions

Dimension	Range of Dimension
Width "w"	about 0.1875 to 0.500 inches
Height "h"	about 5 to 12 inches
Length "l"	about 12 to 16 feet
Flat "t"	about 0 to 0.250 inches
angle "α"	about 5 to 60 degrees
angle "β"	about 60 to 90 degrees

[0236] Figure 36 shows an isometric view of the plastic locking spline of a preferred embodiment. Spline 7200 includes a generally vertical plate 7205, a plate back surface 7210, a first flange 7215, a first flange top surface 7220, a second flange 7230, a third flange 7240, a third flange top surface 7245, and a fourth flange 7255. Spline 7200 has a length "l", a width "w", and a height "h". An example of spline 7200 dimensions include "l" between about 12 and 16 feet, "w" between about 3/8 and 3/4 inches, and "h" between about 1/2 and 2 inches. A cross-sectional diagram of spline 7200 is shown in Figure 37.

[0237] Figure 37 is a cross-sectional diagram of spline 7200 taken along line 37-37 of Figure 36. In this view, additional details of the spline 7200 are visible. Spline 7200 further includes a first flange bottom surface 7225, a second flange front surface 7235, a third flange bottom surface 7250, and a fourth flange front surface 7260. Also shown is plate 7205, plate back surface 7210, first flange 7215, first flange top surface 7220, second flange 7230, third flange 7240, third flange top surface 7245, and fourth flange 7255.

[0238] A first edge of first flange 7215 is integrally connected at an angle to a first edge of elongated plate 7205. A second edge of elongated plate 7205 is integrally connected at an angle along third flange 7240 between the first and second edges of third flange 7240. A first edge of fourth flange 7260 is

integrally connected to a second edge of third flange 7240 in parallel with plate 7205. A first edge of second flange 7230 is integrally connected along first flange 7215 between the first and second edges of first flange 7215 in parallel with plate 7205. Second flange 7230 and fourth flange 7260 are coplanar.

[0239] Figure 38 is an end view of spline 7200. Approximate dimensions and angles of a preferred embodiment of spline 7200 are indicated in Table 6.

Table 6: Spline 7200 dimensions

Dimension	Range of Dimension
Width "w"	about 0.375 to 0.750 inches
Height "h"	about 0.500 to 2.0 inches
Length "l" (shown in Figure 36)	about 12 to 16 feet
"a"	Plank 100 width* – 0.0625 inches
"b"	w – a
"c"	Plank 100 width* – 0.0625 inches
"d"	(h – e) to (0.1 x h)
"e"	(h – d) to (0.1 x h)
"f"	about 0.020 to 0.080 inches
"α"	about 5 to 60 degrees
"β"	about 60 to 90 degrees
* Plank 100 width = about 0.375 to 0.500 inches	

[0240] Figure 39 is a cross-sectional diagram of plank assembly 7400 taken along line 39-39 of Figure 33. In this view, additional details of the plank assembly 7400 are visible. Plank assembly 7400 further includes a first adhesive layer 7410, a second adhesive layer 7420, and a third adhesive layer 7430. With continuing reference to Figure 39, the position of spline 7200 is shown in relation to plank 7100. First flange top surface 7220 forms a landing adapted to support a bottom portion of the plank 7100 and is fixedly connected to plank bottom surface 7110 with first adhesive layer 7410. Second flange front surface 7235, which forms part of the landing, is fixedly connected to plank back surface 7120 with second adhesive layer 7420. Fourth flange front surface 7260 is fixedly connected to plank back surface 7120 with third adhesive layer 7430. Third adhesive layer 7430 is formed to direct water away from the joint.

[0241] Adhesive layer 7410, 7420 and 7430 is preferably a fast setting, reactive hot-melt polyurethane such as H.B. Fuller 2570x or H.B. Fuller 9570 with a viscosity of about 10,000 to 100,000 CPS at application temperatures ranging from about 200° to 350°F. The adhesion time ranges from about 3 to 5 seconds.

[0242] Figure 40 shows the same details as Figure 39 with the addition of a chamfer 7450. Chamfer 7450 is placed at an angle "ε" relative to plank front surface 7115 and may be flat or slightly rounded. Angle "ε" is preferably in the range of about 30 to 60 degrees. With continuing reference to Figure 40, chamfer 7450 is accomplished by cutting or grinding plank 7100, first adhesive 7410 and spline 7200 such that the three elements are "blended". Chamfer 7450 creates a smooth and aesthetically pleasing drip-edge for plank assembly 7400, suitable for painting. As chamfer 7450 is exposed to the weather, first adhesive 7410 acts as a seal between plank 7100 and spline 7200, blocking wind and moisture.

[0243] Figure 41 shows a two-piece siding plank system of a preferred embodiment. Siding system 7500 includes plank assemblies 7400A, 7400B, 7400C and 7400D, a wall 7510, and nails 7520A, 7520B, and 7520C. Using a well-known blind nailing technique, plank assemblies 7400A, 7400B, 7400C, and 7400D are fixedly connected to wall 7510 using nails 7520A, 7520B, and 7520C, respectively (i.e. nails are driven through plank front surface 7115 of plank 7100 (Figure 35) in proximity to plank top surface 7105).

[0244] Third flange bottom surface 7250 and plate back surface 7210 of plank assembly 7400B are positioned in contact with plank top surface 7105 and plank front surface 7115 of plank assembly 7400A, respectively. Likewise plank assembly 7400C and 7400D are positioned in contact with plank assembly 7400B and 7400C, respectively.

[0245] Another example of this embodiment is a two-piece siding plank assembly with a plastic spline and lock, wherein the plastic spline has one or more dove-tail grooves in the first flange top surface, second flange front surface, and fourth flange front surface, with the grooves running along the length of the surfaces, such as described below.

[0246] Figure 42A shows a cross-sectional view of spline 7200 with the above-mentioned dovetail grooves. The exploded view in Figure 42B shows one or more dovetail grooves in first flange top surface 7220, second flange front surface 7235 and fourth flange front surface 7260 of spline 7200. The dovetail groove 7220 provides a mechanical bond together with the adhesive bond to plank 7100 of plank assembly 7400 (Figure 33). This is illustrated in Figures 43A and 43B.

[0247] Figure 43A shows a cross-sectional view of plank assembly 7400. The exploded view in Figure 43B illustrates the interface of spline 7200, adhesive layer 7410, 7420 or 7430 and plank 7100. Figure 43B shows adhesive layer 7410, 7420 or 7430 filling the dovetail grooves of spline 7200. Due to the dissimilar expansion attributes (temperature and moisture) between plank 7100 and spline 7200, stresses are induced in adhesive layers 7410, 7420 and 7430. In the event that the adhesive bond between the adhesive layers and the plastic spline fails due to these stresses, there is still a mechanical connection by means of the dovetail groove(s).

[0248] Another example of this embodiment is a two-piece siding plank assembly using a plastic spline without a lock, without an overlap guide (such as formed by the third flange 7240 of Figure 36), and with or without dovetail grooves, as shown in Figures 44A and 44B. Figures 44A and 44B show a two-piece siding plank assembly 7600 and siding system 7700, respectively. Plank 7610 is identical to plank 7100 of Figure 33 except that plank top surface 7105 (Figure 35) is not angled. Spline 7620 is identical to spline 7200 of Figure 33 except that third flange 7240 (Figure 36) is not extended to create the locking mechanism. Siding system 7700 is assembled as described in Figure 44B except that the gauge of the plank must be measured during the installation process. This embodiment will create a thick butt (deep shadow line) but does not provide a natural overlap guide for installation.

[0249] Another example of this embodiment is a two-piece siding plank assembly using a plastic spline without a lock and with or without dovetail grooves as shown in Figures 45A and 45B. Figures

45A and 45B shows a two-piece siding plank assembly 7800 and siding system 7900, respectively. Plank 7810 is identical to plank 7610 of Figure 44A. Spline 7820 is similar to spline 7200 of Figure 33 except that fourth flange 7255 (Figure 36) is eliminated and third flange 7240 (Figure 36) is shortened and angled to about 90°. Siding system 7900 is assembled as described in Figure 45B. This embodiment will create a thick butt (deep shadow line) and provide a natural overlap guide for easy installation, but will not handle high wind loads.

[0250] Another example of this embodiment is a two-piece plank for a siding application using a natural wood or engineered wood siding plank bonded with an adhesive to a plastic spline with or without a lock.

[0251] Figure 46 shows a flow chart 7950 of the method for making a two-piece plank assembly using an FC siding plank bonded with an adhesive to a plastic spline that involves:

[0252] *Manufacturing plank 7960:* A plank is formed according to conventional Hatschek methods. The plank top and bottom edges are cut to an angle using angled water jet cutters during the conventional Hatschek manufacturing process. The plank is pre-cured then autoclaved as per conventional methods. See Table 5 for preferred ranges of plank dimensions.

[0253] *Pre-treatment of plank & spline 7970:* Plank 7100 and plastic spline 7200 (manufactured according to Table 6) are pre-cut to a desired and equal length. The surfaces of plastic spline 7200 are pre-treated in one of four ways to improve the adhesive bonding capabilities. The four methods of pre-treating the surfaces of the plastic spline are:

Sanding, using conventional power sanding tools;

Cleaning, using a solvent such as Isopropyl Alcohol;

Flame, expose to oxidizing flame fueled by propane gas for about 0.5 to 4 seconds;

A combination of the above.

[0254] *Bonding plank & spline 7980:* Plank 7100 is bonded to plastic spline 7200 to form the plank assembly 7400 shown in Figure 33. Plank 7100 is placed on a first conveyer traveling at a rate up to about 250 feet/minute and three beads of polymeric hot-melt adhesive are applied at a rate of about 1 gram/foot per bead along the length of the plank. The beads are formed so as to align with first flange top surface 7220, second flange front surface 7235, and fourth flange front surface 7260 of spline 7200 (Figure 37). Spline 7200 is placed on a second conveyer traveling at a rate up to 250 feet/minute. The first and second conveyers feed plank 7100 and spline 7200, respectively, to a common destination such that the spline aligns to the plank, makes contact with the adhesive, and is fed into a "nip" machine. The rollers of the nip machine are set to the desired overall plank assembly thickness and press plank 7100 and spline 7200 together. The nip machine then feeds the plank assembly 7400 to a press where about 2 to 10 psi of pressure is applied for about 3 to 5 seconds.

[0255] *Finishing plank assembly 7990:* Plank assembly 7400 is cut to a specified length and chamfer 7450 is applied (Figure 40) using conventional cutting or grinding tools.

B. Spline with Square Lock

[0256] The embodiments above using a "V" style lock system allow planks to be locked into one another without requiring extensive measurement to maintain gauge (the visible vertical distance between planks) and overlap (the vertical distance the plank overhangs the plank below) during installation. While the "V" style lock design has many inherent advantages, this design does not function satisfactorily for small variations in gauge that are sometimes desired by installers, especially when trying to level-out inaccuracies in framing and installation around window and door openings. As a result of being poorly fitted, the plank may subsequently experience lateral movement (flapping) when subjected to wind. Rather, a lock design that allows for small variations in gauge while preventing lateral movement (flapping) when subjected to wind would be beneficial.

[0257] Figure 47 shows an isometric view of the siding plank assembly of another embodiment of the present invention that solves these problems. Plank assembly 8400 includes a plank 8100 and a spline 8200. Plank 8100 is preferably a siding plank manufactured of medium-density FC material using the well-known Hatschek process. Further information regarding the manufacture of plank 8100 may be found in Australian Patent No. AU 515151.

[0258] Spline 8200 is preferably a "butt and lock" type spline made of rigid plastic formed by extrusion. Spline 8200 is aligned and is fixedly connected with an adhesive to plank 8100 (described in greater detail below). Figure 48 shows an isometric view of the FC siding plank of a preferred embodiment. Plank 8100 is a siding plank that includes a plank back surface 8120, a plank key 8125, a plank key back surface 8135, and a nailing region 8145. Plank 8100 has a length "l", a width "w", and a height "h." An example of plank 8100 dimensions include "l" between about 12 and 16 feet, "w" between about 3/16 and 1/2 inches, and "h" between about 5 and 12 inches. A cross-sectional diagram of plank 8100 is shown in Figure 49.

[0259] Figure 49A is a cross-sectional diagram of plank 8100 taken along line 49-49 of Figure 48. In this view, additional details of the plank 8100 are visible. Plank 8100 further includes a plank top surface 8105, a plank bottom surface 8110, a plank front surface 8115, a plank key front surface 8130, and a bevel edge 8140. Also shown is plank back surface 8120, plank key 8125, plank key back surface 8135, and nailing region 8145.

[0260] Plank top surface 8105 is set at an angle "d" to plank key front surface 8130. Angle "d" of plank 8100 is cut using angled water jet cutters during the normal Hatschek manufacturing process. Plank 8100 has a key depth "a," a key height "b," and a nailing region "c."

[0261] Figure 49B is an exploded view of the plank top surface 8105 taken along line 49B-49B. In addition to being set at an angle "d" to the plank key front surface 8130, the plank top surface 8105 has a cant. The cant has a depth "e" from the plank key back surface 8135 and a height "f." Preferred dimensions and angles of plank 8100 are indicated in Table 7.

Table 7. Preferred Plank 8100 dimensions

Dimension	Range of Dimension
Length "l"	about 12 to 16 feet
Width "w"	about 0.1875 to 0.50 inches
Height "h"	about 5 to 12 inches
Key depth "a"	("t" of Table 8) + (about 0.0625 to 0.375) inches
Key height "b"	("d" of Table 8) + about 0.125 inches
Nailing region "c"	about 0.250 to 1.0 inches
Top angle "d"	about 0° to 20°
"e"	about 0.0 to 0.125 inches
"f"	about 0.0 to 0.125 inches

[0262] Figure 50 shows an isometric view of the plastic locking spline of a preferred embodiment. Spline 8200 includes a plate 8205, a plate back surface 8210, a first flange 8215, a first flange top surface 8220, a second flange 8230, a third flange 8240, a fourth flange 8255, a fifth flange 8265, and a fifth flange back surface 8275. Spline 8200 has a length "l," a width "w," and a height "h."

[0263] Figure 51 is a cross-sectional diagram of spline 8200 taken along line 51-51 of Figure 50. In this view, additional details of the spline 8200 are visible. Spline 8200 further includes a plate front surface 8212, a first flange bottom surface 8225, a second flange front surface 8235, a third flange top surface 8245, a third flange bottom surface 8250, a fourth flange front surface 8260, and a fifth flange front surface 8270. Also shown is plate 8205, plate back surface 8210, first flange 8215, first flange top surface 8220, second flange 8230, third flange 8240, fourth flange 8255, fifth flange 8265, and fifth flange back surface 8275. All elements are present along the entire length of spline 8200 as shown in Figure 50.

[0264] A first edge of first flange 8215 is integrally connected orthogonal or at an angle to a first edge of plate 8205 extending from plate front surface 8212. A second edge of plate 8205 is integrally connected at an angle along third flange 8240 between the first and second edges of third flange 8240 extending from third flange bottom surface 8250. A first edge of fourth flange 8260 is integrally connected to a first edge of third flange 8240 in parallel with plate 8205 extending from third flange bottom surface 8250. A first edge of second flange 8230 is integrally connected orthogonal or at an angle along first flange 8215 between the first and second edges of first flange 8215 in parallel with plate 8205 extending from first flange top surface 8220. Second flange 8230 and fourth flange 8260 are coplanar. A first edge of fifth flange 8265 is integrally connected to a second edge of third flange 8240 in parallel with plate 8205 extending from third flange bottom surface 8250.

[0265] Figure 52 is an end view of spline 8200. Preferred dimensions and angles of spline 8200 are indicated in Table 8 below.

Table 8: Preferred Spline 8200 dimensions

Dimension	Range of Dimension
Length "l" (not shown)	about 12 to 16 feet
Width "w"	about 0.375 to 0.750 inches
Height "h"	about 0.500 to 2.0 inches
Thickness "t"	about 0.020 to 0.080 inches
"a"	Plank 8100 width* – about 0.0625 inches
"b"	w – a
"c"	Plank 8100 width* + (about 0.0 to 0.040) inches
"d"	about 0.250 to 1.50 inches
"e"	(h-f) to (0.1 x h)
"f"	(h-e) to (0.1 x h)
"g"	about 0° to 20°
"k"	about 90° to 120°
* Plank 8100 width = about 0.375 to 0.500 inches	

[0266] There is no gap if h = e + f. The gap is provided to save material and to eliminate the need for an extrusion mandrel to form the hollow, thereby simplifying the manufacturing process.

[0267] Figure 53 is a cross-sectional diagram of plank assembly 8400 of Figure 47. In this view, additional details of the plank assembly 8400 are visible. Plank assembly 8400 further includes a first adhesive layer 8410, a second adhesive layer 8420, and a third adhesive layer 8430. With continuing reference to Figure 53, the position of spline 8200 is shown in relation to plank 8100. First flange top surface 8220 is fixedly connected to plank bottom surface 8110 with first adhesive layer 8410. Second flange front surface 8235 is fixedly connected to plank back surface 8120 with second adhesive layer 8420. Fourth flange front surface 8260 is fixedly connected to plank back surface 8120 with third adhesive layer 8430.

[0268] Adhesive layers 8410, 8420 and 8430 are preferably fast setting, reactive hot-melt polyurethane such as H.B. Fuller 2570, H.B. Fuller 9570, or PURMELT R-382-22 with a viscosity of about 10,000 to 100,000 CPS at application temperatures ranging from about 200° to 350°F. The adhesion time preferably ranges from about 3 to 5 seconds. Figure 54 shows the same details as Figure 53 with the addition of a chamfer 8450. Chamfer 8450 is placed at an angle "ε" relative to plank front surface 8115 and may be flat or slightly rounded. Angle "ε" is in the range of about 15° to 85°. One example of angle "ε" is about 45°.

[0269] With continuing reference to Figure 54, chamfer 8450 is accomplished by cutting or grinding plank 8100, first adhesive 8410 and spline 8200 such that the three elements are "blended". Chamfer 8450 creates a smooth and aesthetically pleasing drip-edge for plank assembly 8400, suitable for painting. As chamfer 8450 is exposed to the weather, first adhesive 8410 acts as a seal between plank 8100 and spline 8200, blocking wind and moisture.

[0270] Figure 55 shows a two-piece siding plank system of a preferred embodiment. Siding system 8500 includes a plank assembly 8400A and 8400B, a wall 8510, a wall outer surface 8515, and a nail 8520. Plank assembly 8400A includes a plank 8100A and a spline (that is not shown). Plank assembly 8400B includes a plank 8100B and a spline 8200B.

[0271] Using a blind nailing technique, plank assembly 8400A is fixedly connected to wall 8510 by driving nail 8520 through plank front surface 8115 of plank 8100 (Figure 54) in nailing region 8145 located just below the area of plank key 8125 (Figure 49A). Plate back surface 8210 (Figure 50) of spline 8200B is in contact with plank key front surface 8130 (Figure 49A) of plank 8100A. Fifth flange front surface 8270 (Figure 51) of spline 8200B is in contact with plank key back surface 8135 (Figure 48) of plank 8100A. A small gap in the range of about 0.0 to 0.125 inches is present between fifth flange back surface 8275 (Figure 51) of spline 8200B and wall outer surface 8515. Bevel edge 8140 (Figure 49A) of each plank assembly allows for easy installation of one plank assembly to another.

[0272] If plank assembly 8400A and 8400B of siding system 8500 is tightly fit, third flange bottom surface 8250 (Figure 51) of spline 8200B is in contact with plank top surface 8105 (Figure 49A) of plank 8100A. However, in the case where plank assembly 8400A and 8400B of siding system 8500 is loosely fit, third flange bottom surface 8250 (Figure 51) of spline 8200B is not in contact with plank top surface 8105 (Figure 49A) of plank 8100A leaving a gap "y" in the range preferably of about 0.0 to 0.25 inches. Gap "y" allows easy leveling of the plank assemblies during installation. In either a tightly or loosely fit siding system the plastic spline of the preferred embodiment prevents lateral movement of plank assembly 8400 when installed.

[0273] Another example of this embodiment is a two-piece siding plank assembly with a plastic spline and square lock, wherein the plastic spline has one or more dovetail grooves in the second plate top surface and third plate front surface, with the grooves running along the length of the surfaces as described above in greater detail.

[0274] Another example of this embodiment is a two-piece siding plank assembly with a plastic spline and square lock, wherein the plastic spline has a capillary break in the first plate back surface running along the length of the surface as described below in greater detail.

[0275] Another example of this embodiment is a two-piece siding plank assembly with a plastic spline and square lock, wherein the siding plank is made of any suitable material including but not limited to wood, engineered wood, or composite wood plastic.

[0276] Another example of this embodiment is a one-piece molded or extruded siding plank having a similar cross-sectional shape and providing the same functions as the two-piece siding plank assembly of the first embodiment. In this example, a one-piece siding plank is formed using conventional co-extrusion method or a variable composition fibrous cementitious structural product formed by co-extrusion.

[0277] Another example of this embodiment is a one-piece siding plank having a similar cross-sectional shape and providing the same functions as the two-piece siding plank assembly of the previous embodiment. In this embodiment a one-piece siding plank is formed using Applicant's skin and core technology, as described in pending U.S. Application Serial No. 09/973,844, filed October 9, 2001, the entirety of which is hereby incorporated by reference.

[0278] Figure 56 shows a method for making a two-piece plank assembly using a FC siding plank bonded with an adhesive to a plastic spline, which involves:

[0279] *Manufacturing plank 8960:* A medium-density plank is prepared according to conventional Hatschek methods. Plank key 8125 and nailing region 8145 of plank 8100 (Figure 48) are formed by placing a sleeve of a profiled, offset thickness equal to key depth "a," on the size roller of the Hatschek machine for a distance equal to key height "b" and nailing region "c." As a result, the FC green sheet rides on the sleeve creating the offset of plank key 8125 and nailing region 8145. Alternately, plank key 8125 and nailing region 8145 are formed by profiled press-rollers, where about 200 to 500 psi of pressure is applied to shape these regions. The plank top and bottom edges are cut using angled water jet cutters during the conventional Hatschek manufacturing process. The plank is pre-cured then autoclaved as per conventional methods. See Table 7 above for acceptable ranges of plank dimensions for this embodiment.

[0280] *Pre-treatment of plank & spline 8970:* Plank 8100 and spline 8200 (manufactured as per Table 8) are pre-cut to a desired and equal length as shown in Figure 49A and 50, respectively. The surfaces of plastic spline 8200 (i.e. first flange top surface 8220, second flange front surface 8235, and fourth flange front surface 8260) are pre-treated in one of four ways to improve the adhesive bonding capabilities. The four methods of pre-treating the surfaces of the plastic spline are:

1. Sanding, using conventional power sanding tools to roughen the surface;
2. Cleaning, using a solvent such as Isopropyl Alcohol;
3. Flame, expose to oxidizing flame fueled by propane gas for about 0.5 to 4 seconds;
4. A combination of the above.

[0281] *Bonding plank & spline 8980:* Plank 8100 is bonded to plastic spline 8200 to form the plank assembly 8400 shown in Figure 47. Plank 8100 is placed on a first conveyer traveling at a rate up to 250 feet/minute and three beads of polymeric hot-melt adhesive with a viscosity of about 10,000 to 100,000 CPS at application temperatures ranging from about 200° to 350°F are applied at a rate of about 1 gram/foot per bead along the length of the plank. The beads are formed so as to align with first flange top surface 8220, second flange front surface 8235, and fourth flange front surface 8260 of spline 8200 (Figure 51). Likewise, spline 8200 is placed on a second conveyer traveling at a rate equal to the first conveyor. The first and second conveyers feed plank 8100 and spline 8200, respectively, to a common destination such that the spline 8200 aligns to plank 8100, makes contact with the adhesive and is fed into a "nip" machine. The rollers of the nip machine are set to the desired overall plank assembly thickness and press plank 8100 and spline 8200 together. The nip machine then feeds the plank assembly 8400 to a press where about 10 to 100 psi of pressure is applied for about 3 to 5 seconds.

[0282] *Finishing plank assembly 8990:* Plank assembly 8400 is cut to a specified length and chamfer 8450 is applied (Figure 54) using conventional cutting or grinding tools.

[0283] Advantageously, the siding plank assembly of this embodiment allows for small variations in the siding installed while reducing lateral movement (flapping) when subjected to wind. The

assembly also allows for leveling of the planks during installation and can be formed without machining the lock and key. The locking system allows for easy installation and the plank top surface angle does not need to match the spline fourth plate angle.

C. Apparatus for Reducing Capillary Action Between Planks

[0284] In another embodiment, an apparatus for reducing capillary action is provided in the overlap region between two medium-density FC or other siding assemblies when installed. One example is a plastic spline having a capillary break formed by adding a lip along the length of the spline as described below.

[0285] Conventional exterior siding systems also include a "rain screen," which is the combination of an airtight and watertight barrier placed over the exterior surface of the frame to be sided, combined with the siding. The functional purpose of the siding is to keep moisture away from the rain screen inner barrier surface. The siding of FC material, wood or vinyl rain screen is a series of horizontal "planks" which overlap at their upper edges to prevent wind and rain from penetrating to the interior of the rain screen. The rain screen siding system, if properly installed, is very effective at keeping the framing and insulation of the wall dry and airtight under all weather conditions.

[0286] When siding planks are installed on an exterior wall of a building, moisture can find its way into the tight space where adjacent siding planks overlap. While most moisture does not enter because of gravity, the width of the gap in the overlap region is usually small enough that capillary action can occur, allowing moisture to penetrate to the internal barrier of the rain screen or at least into the space between the exterior barrier and the siding planks. As a result, the lapped siding material is not completely effective as a water barrier.

[0287] While increasing the gap between the siding materials when installed reduces the effect of capillary action, the siding becomes more susceptible to wind driven moisture penetration. Therefore, a siding assembly when installed that prevents water penetration due to rain and capillary action while preventing wind driven penetration would be beneficial. What is needed is a design of lap siding that forms a capillary break to stop the rise of water between the two surfaces in the plank overlap region.

[0288] Advantageously, the siding plank assembly of this embodiment reduces capillary action in the siding, thus providing additional moisture protection to the exterior barrier wall and siding interior while maintaining good resistance to wind driven moisture penetration. Furthermore, the assembly keeps the region that is nailed relatively dry, which increases the strength of fiber cement and therefore resistance to dislodgment of the planks by high winds. Another way to solve the problem is to seal the space between the planks with caulk or other type of sealant. However, this adds complexity to the exterior wall system. Alternatively, a gap or groove the length of the plank can be machined in the overlap area. However, this would create a weak point in the plank and would add a manufacturing process step.

[0289] Figure 57 shows an isometric view of the siding plank assembly comprising a two-piece plank having a plastic spline with an angled lock as described above. Plank assembly 9400 includes a plank 9100 and a spline 9200. Plank 9100 is preferably a siding plank manufactured of medium-density FC material

using a well-known Hatschek process. Spline 9200 is a "butt and lock" type spline manufactured of rigid plastic using a well-known extrusion process described above. Spline 9200 is aligned and is fixedly connected with an adhesive to plank 9100 as described above. As shown in Figure 57, spline 9200 of this embodiment further includes a capillary break 9265 running along the length of spline 9200.

[0290] Figure 58 shows an isometric view of the plastic spline with the capillary break of the preferred embodiment. Spline 9200 includes a plate 9205, a plate back surface 9210, a first flange 9215, a second flange 9230, a third flange 9240, and a fourth flange 9255. Also shown is capillary break 9265 in the form of a lip running along the length of plate back surface 9210 along the lower edge.

[0291] Spline 9200 has a length "l", a width "w", and a height "h". An example of spline 9200 dimensions include "l" between about 12 and 16 feet, "w" between about 3/8 and 3/4 inches, and "h" between about 1/2 and 2 inches. A cross-sectional diagram and an end view of spline 9200 are shown in Figures 59 and 60, respectively.

[0292] Figure 59 is a cross-sectional diagram of spline 9200 taken along line 59-59 of Figure 58. Spline 9200 further includes a third flange bottom surface 9250. Also shown is plate 9205, plate back surface 9210, first flange 9215, second flange 9230, third flange 9240, fourth flange 9255, and capillary break 9265.

[0293] A first edge of first flange 9215 is integrally connected at an angle to a first edge of elongated plate 9205. A second edge of elongated plate 9205 is integrally connected at an angle along third flange 9240 between the first and second edges of third flange 9240. A first edge of fourth flange 9255 is integrally connected to a second edge of third flange 9240 in parallel with plate 9205. A first edge of second flange 9230 is integrally connected along first flange 9215 between the first and second edges of first flange 9215 in parallel with plate 9205. Second flange 9230 and fourth flange 9255 are coplanar. Furthermore, material is added such that the first edge of first flange 9215 is extended and is not coplanar with plate back surface 9210, thus forming capillary break 9265.

[0294] Figure 60 is an end view of spline 9200 showing approximate dimensions. Preferred dimensions and angles of spline 9200 are indicated in Table 9 below.

Table 9: Preferred Spline 9200 dimensions

Dimension	Range of Dimension
"w"	about 0.375 to 0.750 inches
"a"	Plank 9100 width* – about 0.0625 inches
"b"	w – a
"c"	Plank 9100 width* – about 0.0625 inches
"d"	(h-e) to 0.1*h
"e"	(h-d) to 0.1*h
"f"	greater than about 0.100 inches
"h"	about 0.500 to 2.0 inches
"l" (not shown)	about 12 to 16 feet
"t"	about 0.020 to 0.080 inches
"α"	about 0 to 60 degrees
"β"	about 90 to 60 degrees
* Plank 9100 width = about 0.375 to 0.500 inches	

Note: if h = d + e there is no gap. The gap is provided to save material.

[0295] Figure 61 shows a two-piece siding plank system as described above. Siding system 9500 includes plank assemblies 9400A and 9400B. Plank assembly 9400B is positioned in contact with plank assembly 9400A. More specifically, third flange bottom surface 9250 (Figure 59) contacts the top of plank assembly 9400A and capillary break 9265 is in contact with plank front surface 9115 of plank assembly 9400A. The result is a gap located above capillary break 9265 between plate back surface 9210 of plank assembly 9400B and plank front surface 9115 of plank assembly 9400A. The resulting gap is equal to dimension "f" of spline 9200 running along the length of siding system 9500.

[0296] Capillary break 9265 of this embodiment provides a gap equal to dimension "f" of spline 9200 preventing capillary action between plank assemblies 9400A and 9400B. At the same time, capillary break 9265 of a preferred embodiment maintains a wind barrier between plank assemblies 9400A and 9400B, as capillary break 9265 is in direct contact to plank front surface 9115, and third flange bottom surface 9250 (Figure 59) contacts the top of plank assembly 9400A.

[0297] Another example of this embodiment, shown in Figure 62, is a plastic spline having a capillary break formed by adding a groove along the length of the spline as described below. As this spline is extruded, the wall thickness is kept constant, and the capillary break is formed by a semicircular indentation in the back surface of the plate and a semicircular protrusion in the front surface of the plate.

[0298] Figure 62 shows an isometric view of the plastic spline with capillary break of this embodiment. Spline 9300 includes a plate 9305, a plate back surface 9310, a first flange 9315, a second flange 9330, a third flange 9340, and a fourth flange 9355. Also shown is capillary break 9365 in the form of a groove running along the length of plate back surface 9310. Spline 9300 has a length "l", a width "w", and a height "h". An example of spline 9300 dimensions include "l" between about 12 and 16 feet, "w" between about 3/8 and 3/4 inches, and "h" between about 1/2 and 2 inches. A cross-sectional diagram and an end view of spline 9300 are shown in Figures 63 and 64, respectively.

[0299] Figure 63 is a cross-sectional diagram of spline 9300 taken along line 63-63 of Figure 62. Spline 9300 further includes a third flange bottom surface 9350 and a plate front surface 9370. Also shown is plate 9305, plate back surface 9310, first flange 9315, second flange 9330, third flange 9340, fourth flange 9355 and capillary break 9365. First edge of first flange 9315 is integrally connected at an angle to a first edge of elongated plate 9305. A second edge of elongated plate 9305 is integrally connected at an angle along third flange 9340 between the first and second edges of third flange 9340. A first edge of fourth flange 9360 is integrally connected to a second edge of third flange 9340 in parallel with plate 9305. A first edge of second flange 9330 is integrally connected along first flange 9315 between the first and second edges of first flange 9315 in parallel with plate 9305. Second flange 9330 and fourth flange 9360 are coplanar. Along the length of plate 9305, between the first and second edge of plate 9305, material is indented in a semicircular fashion along the length of plate back surface 9310 and material is similarly protruding along the length of plate front surface 9370, thus forming capillary break 9365.

[0300] Figure 64 is an end view of spline 9300. Preferred dimensions and angles of spline 9300 are indicated in Table 10 below.

Table 10: Preferred Spline 9300 dimensions

Dimension	Range of Dimension
"w"	about 0.375 to 0.750 inches
"a"	Plank 9100 width* – about 0.0625 inches
"b"	w – a
"c"	Plank 9100 width* – about 0.0625 inches
"d"	(h-e) to 0.1*h inches
"e"	(h-d) to 0.1*h inches
"f"	greater than about 0.1 inches
"g"	greater than about 0.2 inches
"h"	about 0.500 to 2.0 inches
"j"	about 0.250 to 1.0 inches
"l" (not shown)	about 12 to 16 feet
"t"	about 0.020 to 0.080 inches
"α"	about 0 to 60 degree
"β"	about 90 to 60 degree
* Plank 9100 width = about 0.375 to 0.500 inches	

[0301] Figure 65 shows a two-piece siding plank system of a preferred embodiment. Siding system 9600 includes plank assemblies 9400C and 9400D. Plank assembly 9400D is positioned in contact with plank assembly 9400C. More specifically, third flange bottom surface 9350 (Figure 63) contacts the top of plank assembly 9400C and plate back surface 9310 (Figure 63) is in contact with plank front surface 9115 (Figure 61) of plank assembly 9400C. The result is a gap created by the presence of capillary break 9365 between plate back surface 9310 of plank assembly 9400D and plank front surface 9115 of plank assembly 9400C. The resulting gap running along the length of siding system 9600 has a depth substantially equal to dimension "f" of spline 9300 and a width substantially equal to dimension "g" of spline 9300.

[0302] Capillary break 9365 of this embodiment provides a gap equal to dimension "f" of spline 9300 preventing capillary action between plank assemblies 9400C and 9400D. At the same time, capillary break 9365 of the present invention maintains a wind barrier between plank assemblies 9400C and 9400D, as plate back surface 9310 is in direct contact to plank front surface 9115.

VI. FIBER CEMENT ARTICLES WITH LOCALIZED REINFORCEMENT AND A METHOD FOR MAKING SAME

[0303] In additional embodiments, fiber cement articles having localized reinforcements are provided, which is designed in one embodiment for use in combination with a system of FC planks for siding applications. The result is a locally reinforced FC plank assembly having fiber cement articles with localized reinforcements for improving the strength of individual FC siding planks.

[0304] Advantageously, the siding plank assembly of these embodiments provide a lightweight siding assembly having a reduced amount of FC material without compromising the strength of the plank. The addition of localized reinforcement provides for a low-cost siding assembly with increased stiffness and strength, which reduces breakage and improves handleability and ease of installation. The siding assembly is also suitable for blind nailing and capable of high wind loads.

[0305] Figure 66 shows a cross-sectional view of a reinforced fiber cement article 10000, which includes a fiber cement article 11000, a reinforcing fixture 13000, and a high-shear adhesive layer 12000 that is situated between fiber cement article 11000 and reinforcing fixture 13000. High-shear adhesive layer 12000 and reinforcing fixture 13000 can be applied to one or both faces of fiber cement article 11000.

[0306] Fiber cement article 11000 may be made in accordance with the methods described in Australian patent AU 515151, "Fiber Reinforced Cementitious Articles" and in U.S. Patent No. 6,346,146, the entirety of each of which is hereby incorporated by reference. However, it will be appreciated that fiber cement articles manufactured by other means, including but not limited to the Hatschek process, Bison process, filter pressing, flow-on process, Mazza process, Magnani process, roll-forming, or extrusion, can be used in this embodiment.

[0307] High-shear adhesive layer 12000 is preferably an adhesive with high-shear strength, good alkali resistance, durability in exterior cladding applications and quick setting capabilities. The adhesive also preferably has sufficient working or "open" time to allow sufficient penetration into the fiber cement substrate. The adhesive also preferably maintains its adhesive properties through exposure to many cycles of heat and cold and/or wet and dry. One method of evaluating the suitability of such adhesive is to conduct a "peel test", well known in the art, in which the percent retention of peel strength is measured after several exposures to wet and dry and/or heat and cold. Preferably, durable high-shear strength adhesives are used, for instance: hot melt polyurethane adhesives such as Henckel Puremelt 243; hot melt polyamide adhesives such as Henckel - Micromelt 6239, 6238, and 6211; and hot melt modified ethylene vinyl acetate (EVA) adhesives such as Reicholdt 2H850.

[0308] The preferred options listed above for the high-shear strength adhesive layer 12000 have the additional property of resisting adhesive failure after five wet/dry cycles of soaking in saturated CaO (alkaline) solution at 60 °F or after twenty-five soak/freeze/thaw cycles.

[0309] Reinforcing fixture 13000 is preferably made from any common engineering material, preferably with a tensile strength substantially greater than that of fiber cement article 11000. More preferably, the reinforcing fixture is made of a non-rigid material. Preferred materials for reinforcing fixture 13000 including, but not limited to, metal foils, woven metal meshes, and expanded metal meshes of sufficient shape and dimension to be suitable for the application. Other materials of relatively high tensile strength, such as polymer films or woven and non-woven polymer fabric meshes may also be used.

[0310] As shown in Figure 66, both durable high-shear adhesive layer 12000 and reinforcing fixture 13000 are placed on one face of fiber cement article 110000 and centered along the length and width of fiber cement article 11000. When handling reinforced fiber cement article 10000, tensile stresses created by flexing fiber cement article 11000 are transferred to reinforcing fixture 13000 via high-shear adhesive layer 12000.

[0311] Reinforcing fixture 13000 can be applied to both faces of fiber cement article 11000 or can be applied to more than one area of fiber cement article 11000 with high-shear adhesive layer 12000 in order to accommodate stresses envisioned in the use and application of fiber cement article 11000.

[0312] Reinforcing fixture 13000 and durable high-shear strength adhesive layer 12000 may be applied to fiber cement shapes other than flat planks, including, but not limited to, panels, roofing shakes or shingles, tiles, slate, thick boards, and hollow or solid extruded profiles, in order to provide reinforcement in critical areas. Thus, it will be appreciated that the reinforcing fixtures described herein are not limited to siding planks.

[0313] While reinforcing fixture 13000 is illustrated in Figure 66 as a flat sheet, reinforcing fixture 13000 may also have any three-dimensional shape required to provide sufficient reinforcement to specific areas of fiber cement article 11000 when attached to fiber cement article 11000 with durable high-shear adhesive 12000. The dimensions and shape of reinforcing fixture 13000 may be determined by analyzing the stresses in fiber cement article 11000 under specific conditions of load using any number of methods known to the art, including finite element analysis.

[0314] One means of evaluating the relative stiffness of reinforced fiber cement article 10000 is the "barrel test," which measures the ability of a plank to be self-supporting when carried parallel to the ground. In the barrel test, a plank is balanced flat upon the circumference of a barrel placed parallel to the ground. If the plank does not break after a predetermined amount of time, the amount of deflection from horizontal is measured in order to compare the relative stiffness of various plank designs and materials. Table 11 illustrates the relative performance in the barrel test of fiber cement planks made according to the embodiments described herein.

Table 11 Deflection and breaking behavior of FC planks in the barrel test

Article	Deflection and breaking behavior (0 min.)	Deflection and breaking behavior (5 min.)
Control: 5/16" x 8 1/4" x 12 ft. FC plank	16" 50% chance of breaking	N/A
3/16" x 8 1/4" x 12 ft. FC plank	100% chance of breaking	N/A
3/16" x 6" x 12 ft. FC plank laminated with a 6" x 12 ft. steel foil	22" deflection 0% chance of breaking	23" deflection 0% chance of breaking
3/16" x 8 1/4" x 12 ft. FC plank laminated with a 4" x 4 ft. steel foil	28" deflection 0% chance of breaking	29.5" deflection 0% chance of breaking
3/16" x 8 1/4" x 12 ft. FC plank laminated with a 2" x 4 ft. steel foil	36" deflection 0% chance of breaking	39.5" deflection 0% chance of breaking

[0315] Figures 67, 68, and 69 below illustrate examples of fiber cement building products incorporating reinforced fiber cement article 10000.

[0316] Figure 67 shows a front perspective view of a reinforced fiber cement plank with nailing skirt 20000, including fiber cement article 11000, high-shear adhesive layer 12000, and a metal or plastic nailing skirt 23000. Nailing skirt 23000 functions as reinforcing fixture 13000 in this application and is preferably attached to fiber cement article 11000 in the manner described above with reference to reinforcing fixture 13000. Nailing skirt 23000 serves as a nailing area for attaching fiber cement article 11000 to the exterior of a building and is of sufficient thickness to support fiber cement article 11000 when so attached. Nailing through nailing skirt 23000 reduces the amount of overlap required between siding planks. The stiffness of nailing skirt 23000 also provides resistance to wind uplift when the plank is blind nailed.

[0317] Figure 68 shows a rear perspective view of a reinforced fiber cement plank with extruded polymer reinforcing strip 30000, including fiber cement article 11000, high-shear adhesive layer 12000, and a three-dimensional reinforcing fixture 33000. Three-dimensional reinforcing fixture 33000 functions as reinforcing fixture 13000 in this application and is attached to fiber cement article 11000 in the manner described above with reference to reinforcing fixture 13000. Three-dimensional reinforcing fixture 33000 functions both to stiffen the plank and as a spacer between planks when several planks are installed on a wall. By providing the function of a spacer, the reinforcing fixture 33000 provides an aesthetically pleasing shadow line when several planks are installed on the wall.

[0318] Figure 69 shows a rear perspective view of a multi-lap fiber cement plank 40000, including two or more fiber cement articles 11000 joined in an overlapping fashion and bonded together with high-shear adhesive layer 12000.

[0319] Figure 70 shows a method 50000 for making a fiber cement article with a localized reinforcing fixture, which involves:

[0320] *Designing reinforcing fixture 51000:* Analyze the stresses on the fiber cement article in its intended use to determine the shape, dimension, and appropriate material for the reinforcing

fixture. The analysis and design is performed using methods well known in the art, such as classical bending moment analysis or finite element analysis.

[0321] *Fabricating reinforcing fixture 52000:* Fabricate the reinforcing fixture 13000 using well-known methods appropriate for the design and material generated in step 51000. For example, if reinforcing fixture 13000 were a metal foil of specific shape, a die would be fabricated using well-known methods to mechanically stamp the shape from a roll of aluminum foil of a specific thickness.

[0322] *Applying adhesive to article surface 53000:* Form a high-shear strength adhesive layer 12000 of a predetermined thickness by applying a predetermined amount of durable, high-shear strength adhesive to a predetermined location on the surface of fiber cement article 11000. High-shear strength adhesive layer 12000 is preferably applied at a temperature in the range of about 200° F to 400° F such that the viscosity of the adhesive allows sufficient penetration into the fiber cement surface at the application temperature. The durable, high-shear strength adhesive should ideally allow between about 30 and 60 seconds of working (open) time before setting. The adhesive can be applied using any type of commonly used hot melt application equipment, such as a roll coater, curtain coater, or hot glue gun.

[0323] *Applying adhesive to reinforcing fixture surface 54000:* Form a high-shear strength adhesive layer 12000 of a predetermined thickness (when required to ensure adequate bonding between fiber cement article 11000 and reinforcing fixture 13000) by applying a predetermined amount of durable, high-shear strength adhesive to a predetermined location on the surface of reinforcing fixture 13000. The adhesive is preferably applied at a temperature in the range of about 200° F to 400° F such that the viscosity of the adhesive allows it to penetrate into fiber cement article 11000 at the application temperature. The durable, high-shear strength adhesive should ideally allow between about 30 and 60 seconds of working (open) time before setting. The adhesive can be applied using any type of commonly used hot melt application equipment, such as a roll coater, curtain coater, or hot glue gun.

[0324] *Attaching reinforcing fixture to article surface 55000:* Attach a reinforcing fixture 13000 to a fiber cement article 11000 manually or by mechanical means, such that the point of attachment is high-shear adhesive layer 12000 applied in steps 53000 and/or 54000.

[0325] *Applying pressure to reinforcing fixture and article 56000:* Apply a uniform pressure to fiber cement article 11000 and reinforcing fixture 13000 in order to bond reinforcing fixture 13000 to fiber cement article 11000. In the example of reinforced fiber cement plank with nailing skirt 20000, pressure is applied by passing fiber cement article 11000 and reinforcing fixture 13000 simultaneously through the nip of a pressurized roller such that the roller uniformly exerts three pounds per linear inch (25 pounds across a 8.25 inch plank width). Other mechanical means may be used to apply pressure to assemblies of more complicated shapes.

[0326] *Setting adhesive 57000:* Hold fiber cement article 11000 and reinforcing fixture 13000 in place for a predetermined amount of time, pressure, and temperature in order to permanently bond them together. The pressure, time, and temperature required are dictated by the properties of the high-shear

adhesive used and line speed of the manufacturing process. In the example of reinforced fiber cement plank with nailing skirt 20000, hot-melt polyurethane adhesive is applied at 250° F, the components are assembled within 60 seconds, and the plank is instantaneously pressed using a pressurized nip roll.

[0327] *Removing fiber cement article from press 58000:* Remove finished reinforced fiber cement article 10000 from the press using manual or mechanical means.

[0328] The embodiments for localized reinforcement described above advantageously improve the handleability of thin fiber cement planks or other articles by allowing a thin, lightweight plank or article to have the same stiffness as a much thicker, denser plank or article. By using localized reinforcements durably bonded to specific portions of a fiber cement article, the stiffness, bending strength, and /or impact strength of the fiber cement article may be improved, allowing such articles to be used in applications previously unsuitable for fiber cement due to its brittleness. Fiber cement siding planks formed as described above are capable of handling high wind loads when blind nailed, and provide a way to minimize the amount of overlap between fiber cement planks while maintaining a secure attachment. Articles made according to the methods described above also have greater resistance to adhesive failure after exposure to wet/dry cycles, attack by alkaline solutions, or soak/freeze/thaw cycling. Additionally, by using localized reinforcements durably bonded to specific portions of a fiber article, such articles may be designed for a given application using less fiber cement material and/or fiber cement material of a lower density. In the embodiment above using a foil-backed fiber cement planks, such planks are capable of reflecting heat from a building, which keeps the building cooler in hot weather.

[0329] In another embodiment, the problem of providing localized reinforcement to fiber cement articles can be solved by embedding the reinforcing fixture within the fiber cement article while the fiber cement article is in the green or plastic state. Preferably, the reinforcing fixture should be chosen to withstand the high temperature of the curing process of the fiber cement article so as not to lose their effectiveness.

Conclusions

[0330] Certain preferred embodiments of the present invention provide efficient designs for lightweight fiber cement siding plank assemblies having the traditional deep shadow-line. Particularly, the deep shadow line is created without having to machine the siding plank or otherwise remove any siding plank material. Instead, the siding plank is formed by adding material to a thinner starting base siding plank instead of removing material from a thick rectangular section as shown in prior art. Additionally, two pieces of FC material can be bonded solidly and quickly using the adhesive composition of the preferred embodiments. As such, thin and lightweight planks can be used as siding material that produces a thick shadow line.

[0331] Furthermore, the siding plank assembly of certain preferred embodiments provide interlocking features that allow the planks to be installed quickly with ease and maintain a constant gauge of plank rows along the length of the siding and between rows of sidings. The siding plank assembly also

provides the installation flexibility of variable gauge height. The siding plank assemblies use gravity to help mate two planks tightly and uniformly without face nailing.

[0332] Additionally, certain preferred embodiments of the present invention provide for improved handleability and strength of thin fiber cement planks by allowing a thin, lightweight plank to have the same stiffness as a much thinker, denser plank. This is preferably accomplished by reinforcing specific portions of a fiber cement article with reinforcing fixtures. A locally reinforced article has the advantages of producing a low cost article that handles well during installation and under wind loads. The reinforced article also provides a way to minimize the amount of overlap between fiber cement planks while maintaining a secure attachment as well as a way to reflect heat.

[0333] Although the foregoing invention has been described in terms of certain preferred embodiments, other embodiments will become apparent to those of ordinary skill in the art, in view of the disclosure herein. Accordingly, the present invention is not intended to be limited by the recitation of preferred embodiments, but is instead intended to be defined solely by reference to the appended claims.

WHAT IS CLAIMED IS:

1. A reinforced fiber cement article, comprising:

a fiber cement article having a front surface and a back surface; and

a reinforcing fixture bonded along a length of at least one of the front surface and the back surface to improve the strength of the fiber cement article.

2. The reinforced article of Claim 1, further comprising a high-shear strength adhesive layer situated between the fiber cement article and the reinforcing fixture.

3. The reinforced article of Claim 2, wherein the high-shear strength adhesive layer covers a portion of the front surface of the fiber cement article for bonding the reinforcing fixture to the fiber cement article.

4. The reinforced article of Claim 2, wherein the high-shear strength adhesive layer covers a portion of the front surface and the back surface of the fiber cement article for bonding the reinforcing fixture to the front and back surface of the fiber cement article.

5. The reinforced article of Claim 1, wherein the reinforcing fixture has a tensile strength greater than the fiber cement article.

6. The reinforced article of Claim 1, wherein the reinforcing fixture is more flexible than the fiber cement article.

7. The reinforced article of Claim 1, wherein the reinforcing fixture is a metal foil.

8. The reinforced article of Claim 1, wherein the reinforcing fixture is a woven metal mesh.

9. The reinforced article of Claim 1, wherein the reinforcing fixture is a polymer film.

10. The reinforced article of Claim 1, wherein the reinforcing fixture is a polymer fabric mesh.

11. The reinforced article of Claim 10, wherein the polymer fabric mesh is non-woven.

12. The reinforced article of Claim 1, wherein the reinforcing fixture has a thickness, width, and length.

13. The reinforced article of Claim 12, wherein the length of the reinforcing fixture is substantially the same as the length of the fiber cement article.

14. The reinforcing article of Claim 12, wherein the reinforcing fixture is an interlocking member.

15. The reinforcing article of Claim 14, wherein the interlocking member is a butt piece.

16. The reinforcing article of Claim 14, wherein the interlocking member is a plastic spline.

17. The reinforcing article of Claim 12, wherein the reinforcing fixture is a nailing skirt for attaching and supporting the fiber cement article to the exterior of a building.

18. The reinforced article of Claim 1, wherein the fiber cement article is a flat siding plank.

19. The reinforced article of Claim 1, wherein the fiber cement article is a roofing shake.

20. The reinforced article of Claim 1, wherein the fiber cement article has a hollow extruded profile.

21. The reinforced article of Claim 1, wherein the fiber cement article has a length extending from one end to another end of the article and the reinforcing fixture extends along the entire length of the article.

22. A method for making a fiber cement article with a localized reinforcing fixture, comprising:

determining points of stress on the fiber cement article;

selecting a reinforcing fixture for improving the strength of the fiber cement article at the points of stress; and

bonding the reinforcing fixture to the points of stress on the fiber cement article.

23. The method of Claim 22, wherein determining points of stress on the fiber cement article involves analyzing the stresses on the fiber cement article in its installation of intended use.

24. The method of Claim 22, wherein selecting a reinforcing fixture comprises determining the shape, dimension, and appropriate material based on a stress analysis of the fiber cement article in its installation or intended use.

25. The method of Claim 24, wherein selecting a reinforcing fixture further comprises fabricating the reinforcing fixture.

26. The method of Claim 22, wherein bonding the reinforcing fixture to the fiber cement article comprises applying an adhesive to a surface of the article.

27. The method of Claim 26, wherein bonding the reinforcing fixture further comprises applying an adhesive to a surface of the fixture.

28. The method of Claim 26, wherein the reinforcing fixture is attached to a surface of the fiber cement article after an adhesive is applied to the article surface.

29. The method of Claim 28, wherein a pressure is applied to the reinforcing fixture and article after the reinforcing fixture is attached to the surface of the fiber cement article.

30. The method of Claim 29, wherein the fiber cement article and reinforcing fixture are held in place in a press for a predetermined amount of time, pressure, and temperature in order to permanently bond them together.

31. The method of Claim 30, wherein the fiber cement article with the localized reinforcing fixture is removed from the press.

32. The method of Claim 22, wherein the reinforcing fixture selected is an interlocking member.

33. The method of Claim 22, wherein the reinforcing fixture selected is a nailing skirt for attaching and supporting the fiber cement article to the exterior of a building.

34. The method of Claim 22, wherein the fiber cement article is a flat siding plank.

35. The method of Claim 22, wherein the fiber cement article selected from the group consisting of a roofing shake, slate, and tile.

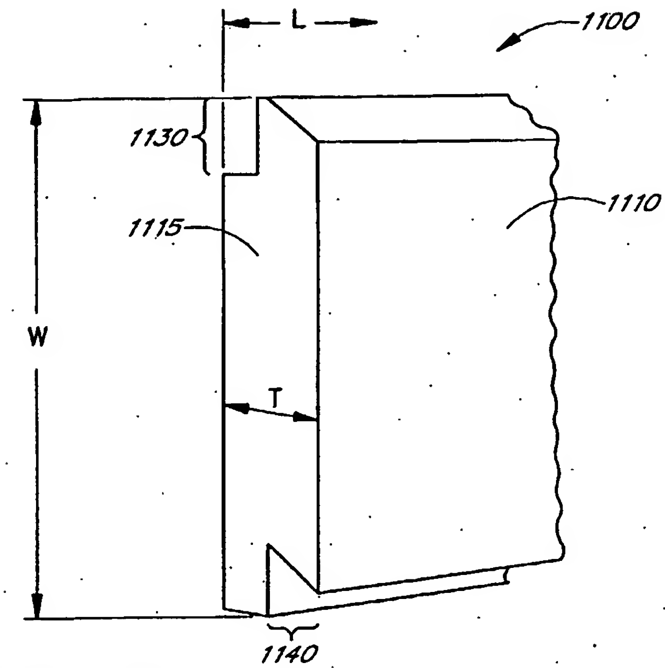


FIG. 1A

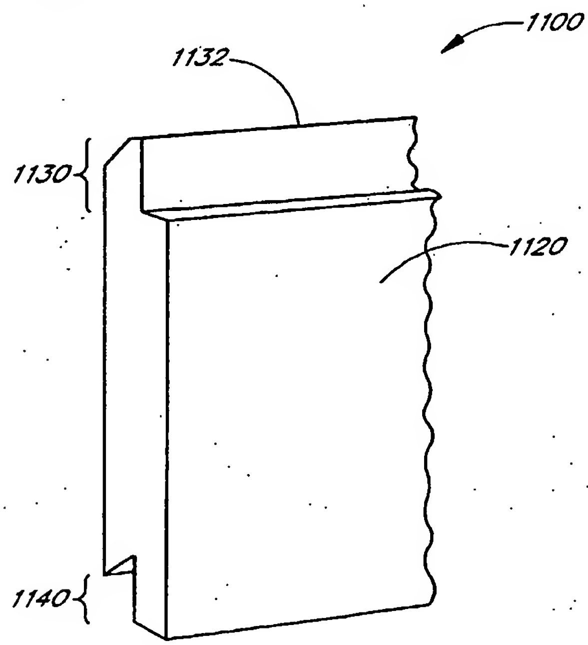


FIG. 1B

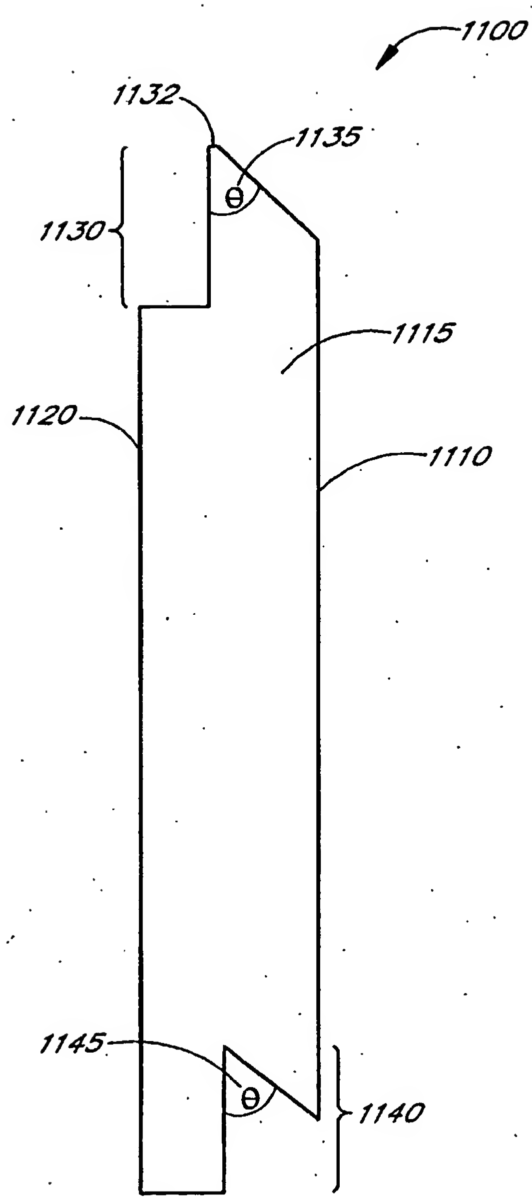


FIG. 2

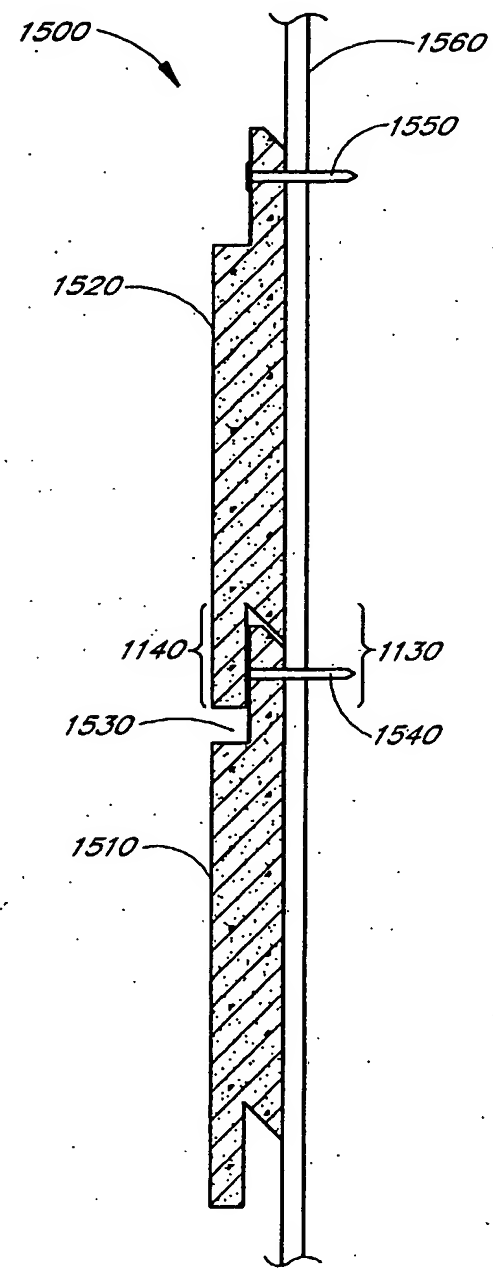


FIG. 3

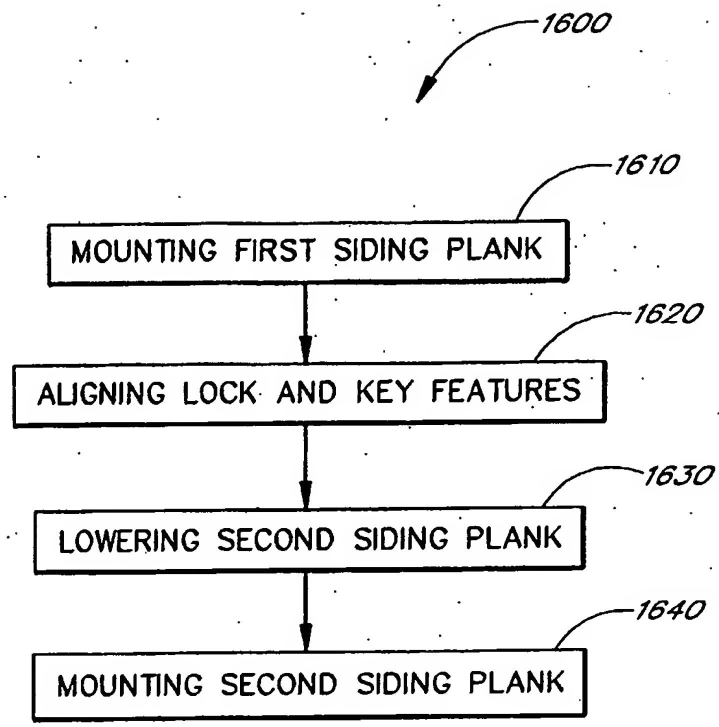

1600
1610
MOUNTING FIRST SIDING PLANK
1620
ALIGNING LOCK AND KEY FEATURES
1630
LOWERING SECOND SIDING PLANK
1640
MOUNTING SECOND SIDING PLANK

FIG. 4

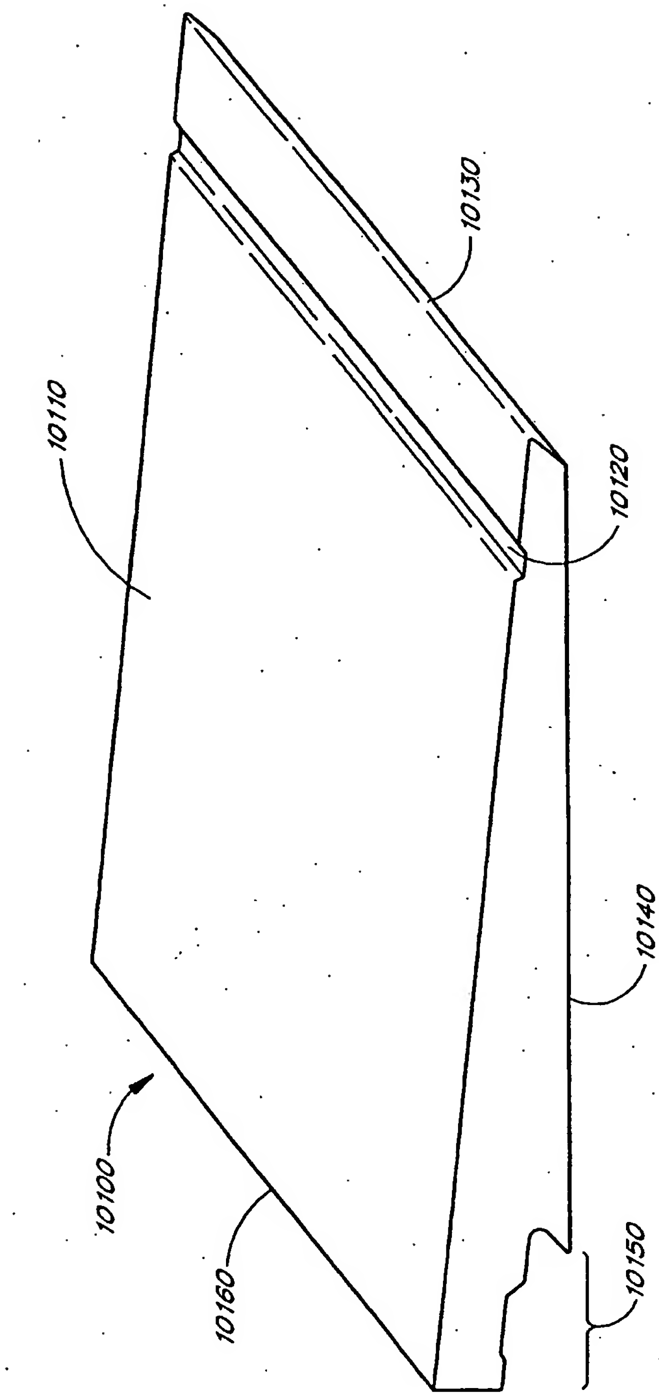


FIG. 5

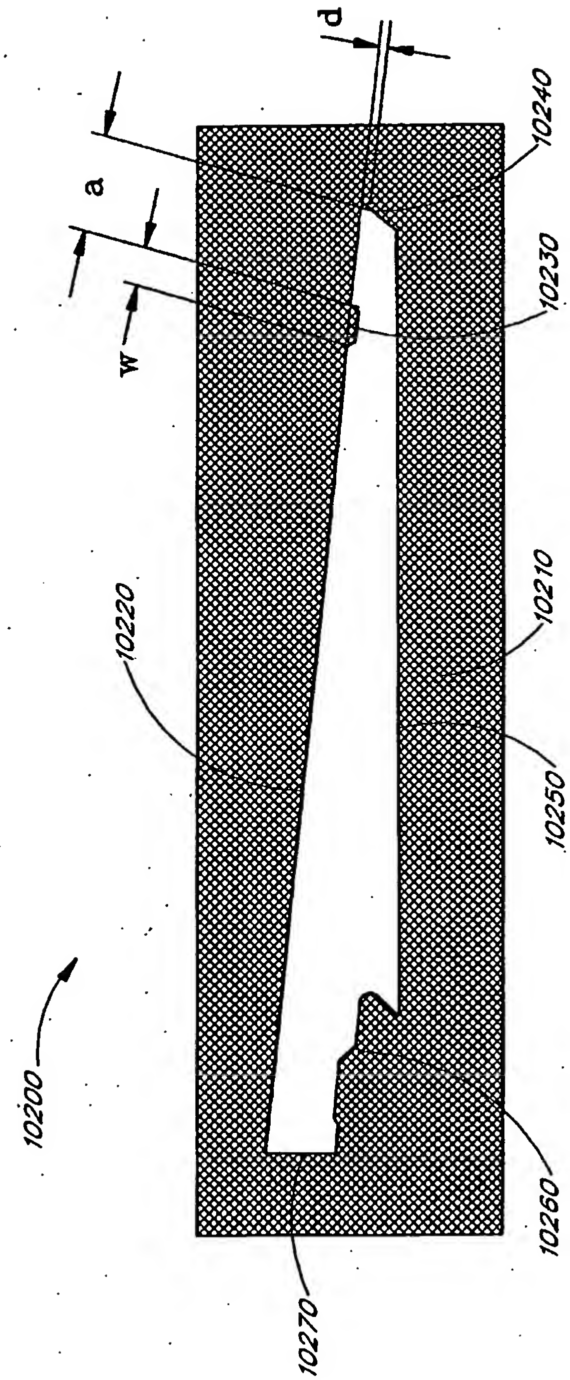


FIG. 6

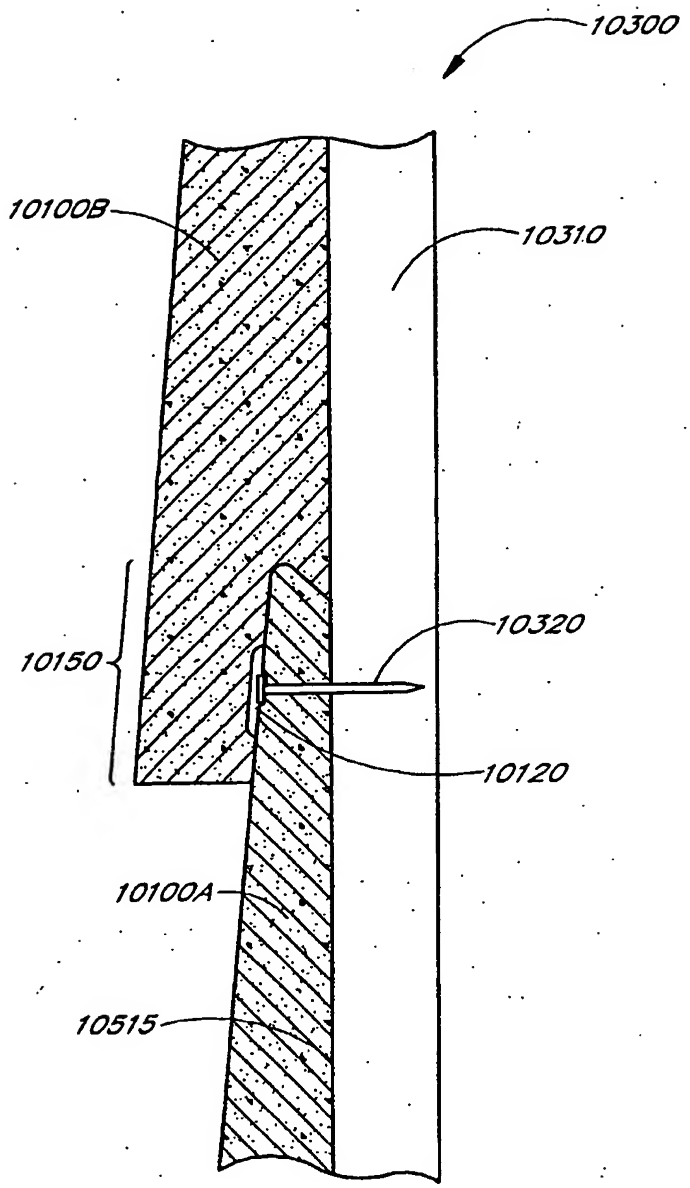


FIG. 7

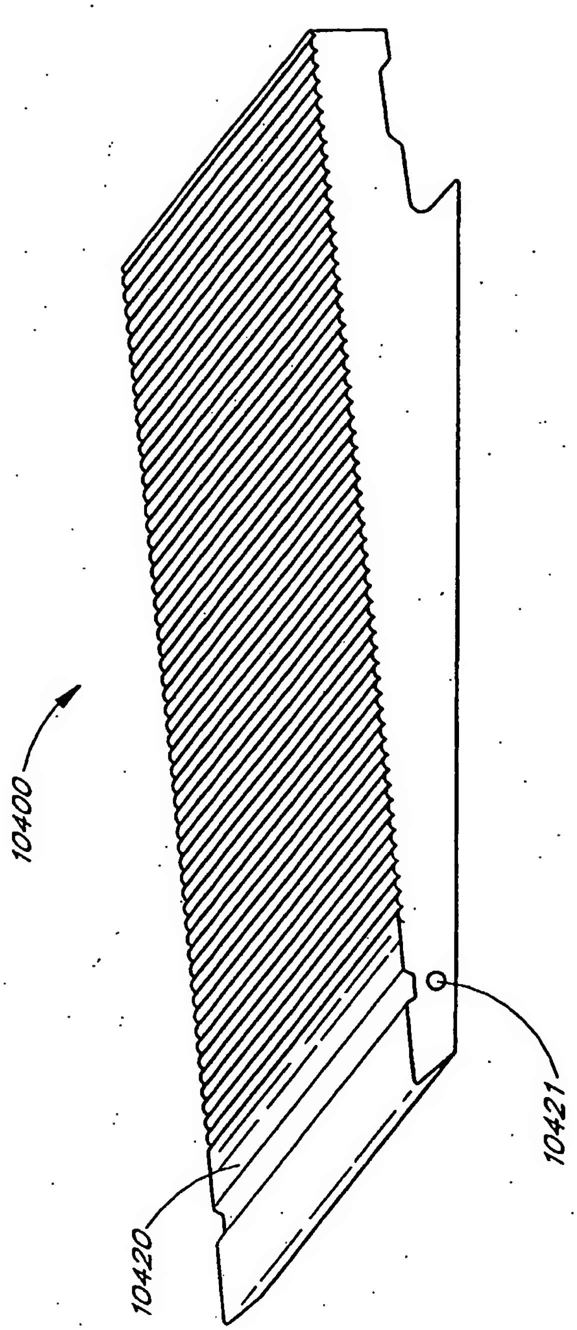


FIG. 8

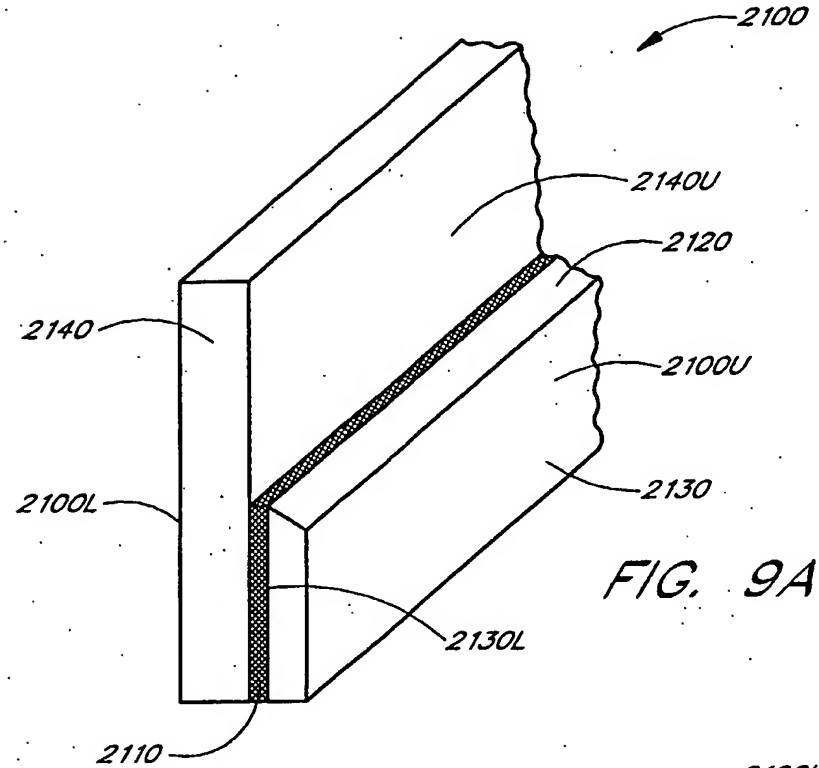

2100
2140U
2120
2140
2100U
2100L
2130
2130L
2110

FIG. 9A

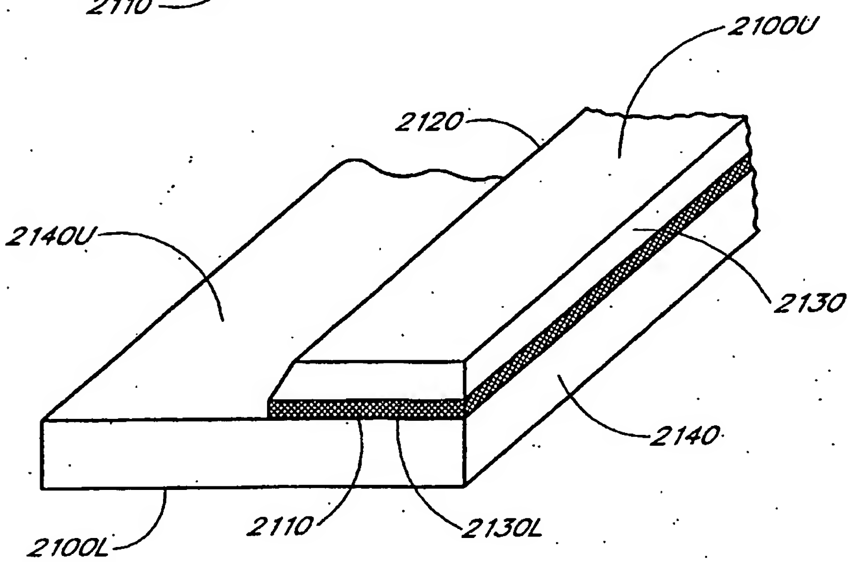

2100U
2120
2140U
2130
2140
2110
2130L
2100L

FIG. 9B

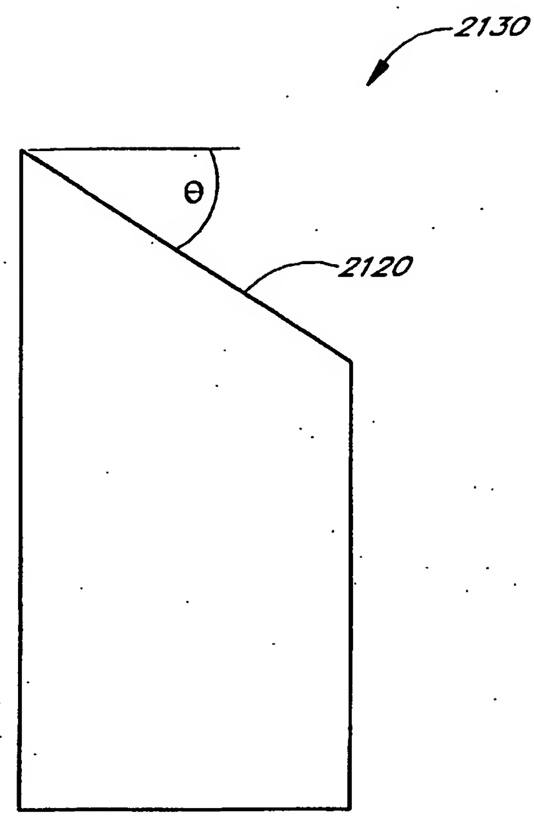


FIG. 10

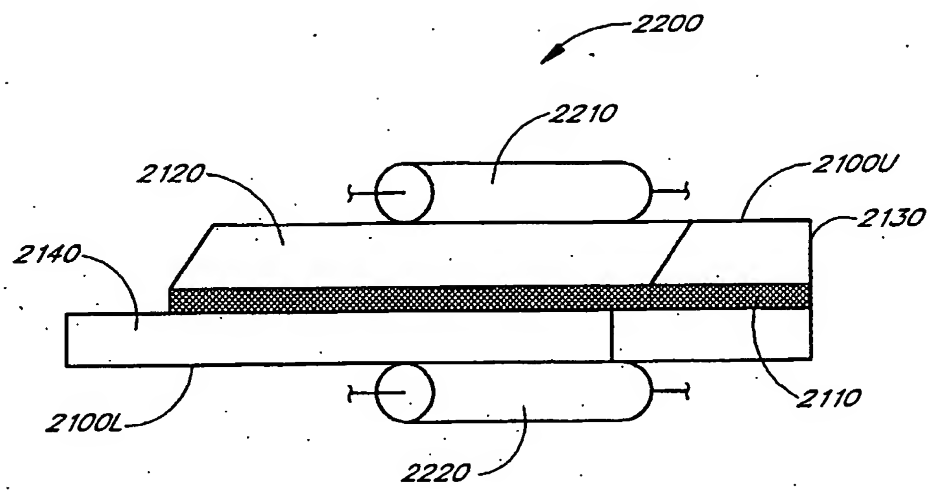


FIG. 11A

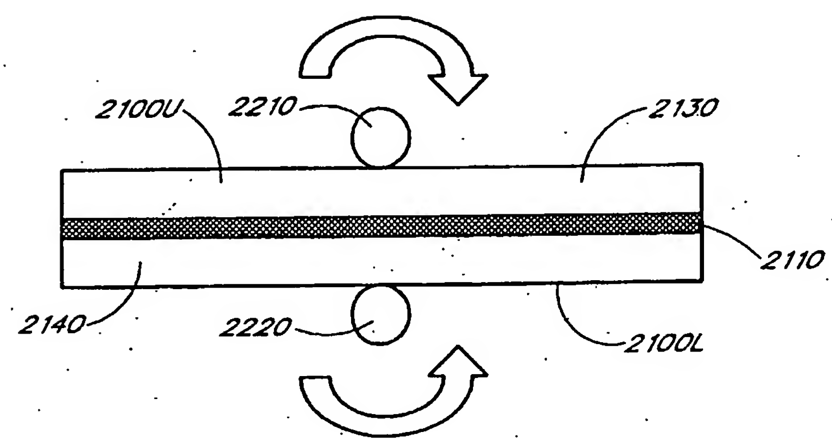


FIG. 11B

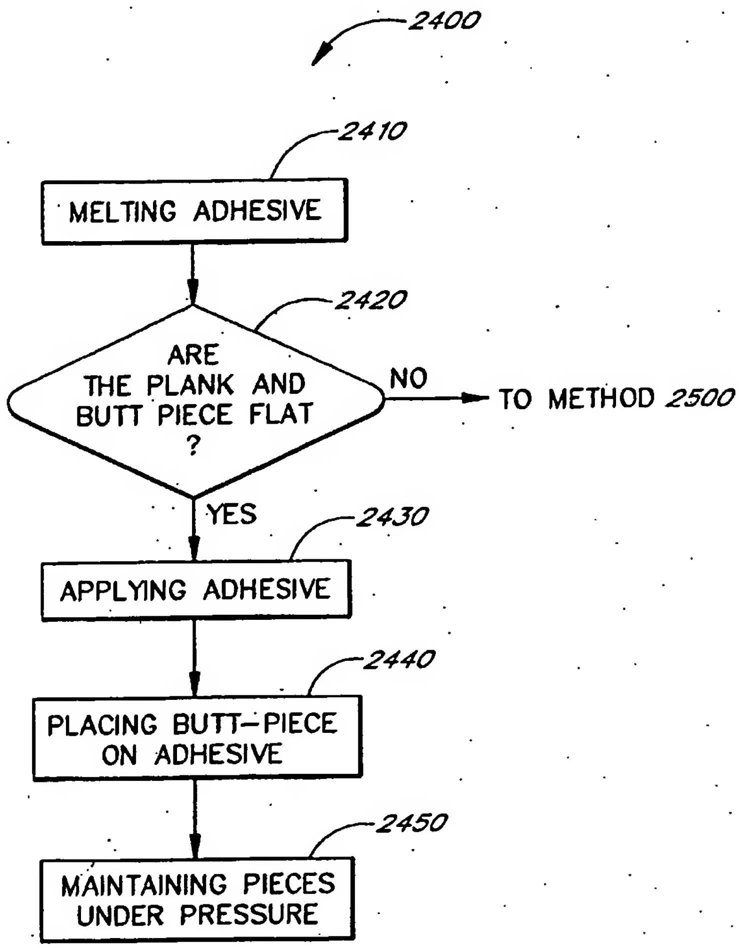

2400
2410
MELTING ADHESIVE
2420
ARE THE PLANK AND BUTT PIECE FLAT ?
NO
TO METHOD 2500
YES
2430
APPLYING ADHESIVE
2440
PLACING BUTT-PIECE ON ADHESIVE
2450
MAINTAINING PIECES UNDER PRESSURE

FIG. 12

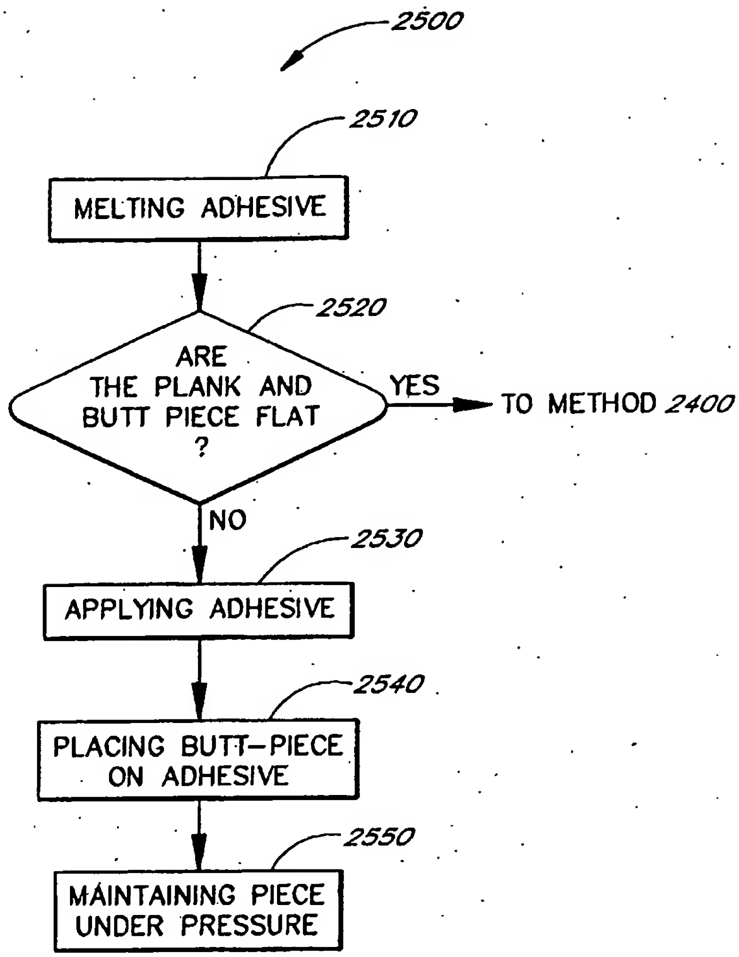

2500
2510
MELTING ADHESIVE
2520
ARE THE PLANK AND BUTT PIECE FLAT ?
YES
TO METHOD 2400
NO
2530
APPLYING ADHESIVE
2540
PLACING BUTT-PIECE ON ADHESIVE
2550
MAINTAINING PIECE UNDER PRESSURE

FIG. 13

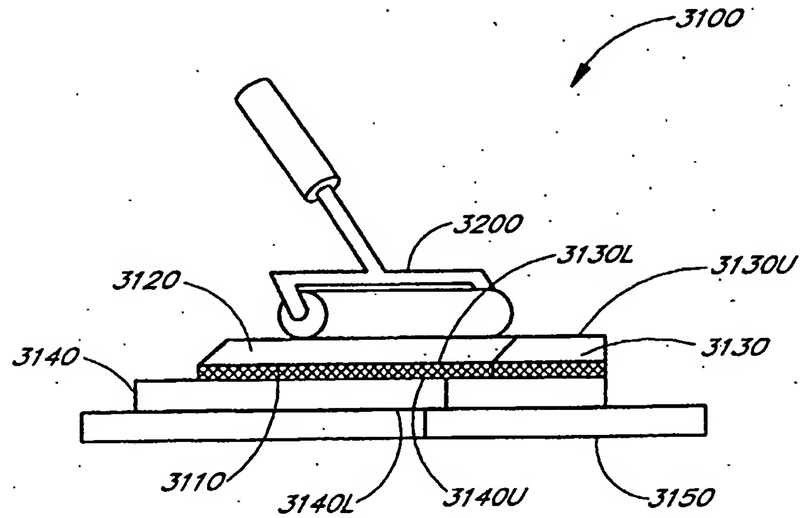


FIG. 14A

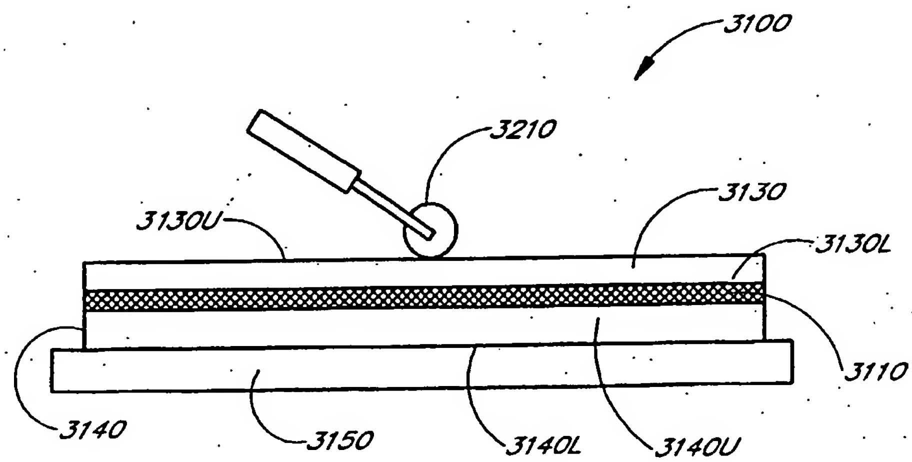


FIG. 14B

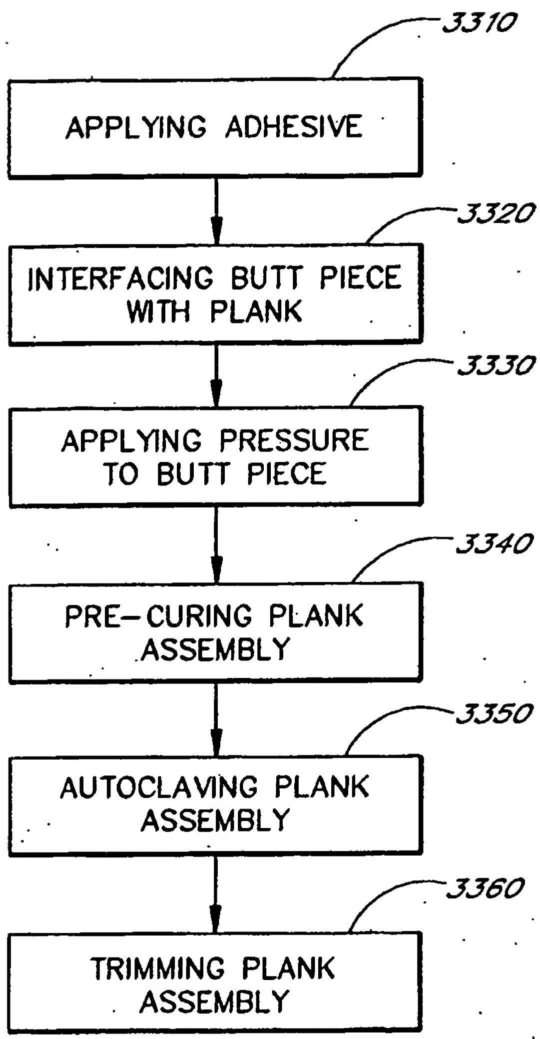

3310
APPLYING ADHESIVE
3320
INTERFACING BUTT PIECE WITH PLANK
3330
APPLYING PRESSURE TO BUTT PIECE
3340
PRE-CURING PLANK ASSEMBLY
3350
AUTOCLAVING PLANK ASSEMBLY
3360
TRIMMING PLANK ASSEMBLY

FIG. 15

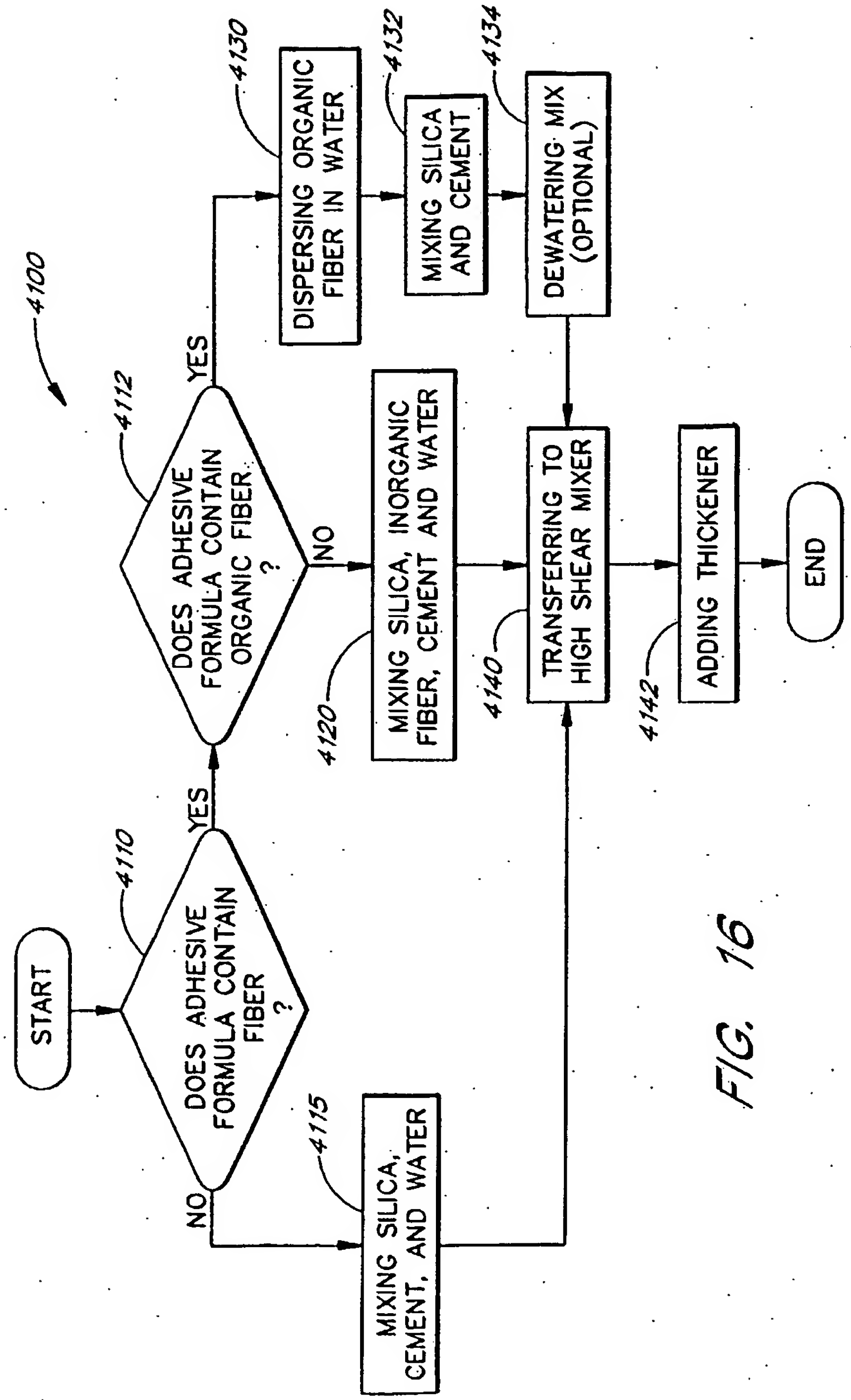

4100
START
DOES ADHESIVE FORMULA CONTAIN FIBER ?
4110
NO
YES
4115
MIXING SILICA, CEMENT, AND WATER
DOES ADHESIVE FORMULA CONTAIN ORGANIC FIBER ?
4112
NO
YES
4120
MIXING SILICA, INORGANIC FIBER, CEMENT AND WATER
4130
DISPERSING ORGANIC FIBER IN WATER
4132
MIXING SILICA AND CEMENT
4134
DEWATERING MIX (OPTIONAL)
4140
TRANSFERRING TO HIGH SHEAR MIXER
4142
ADDING THICKENER
END

FIG. 16

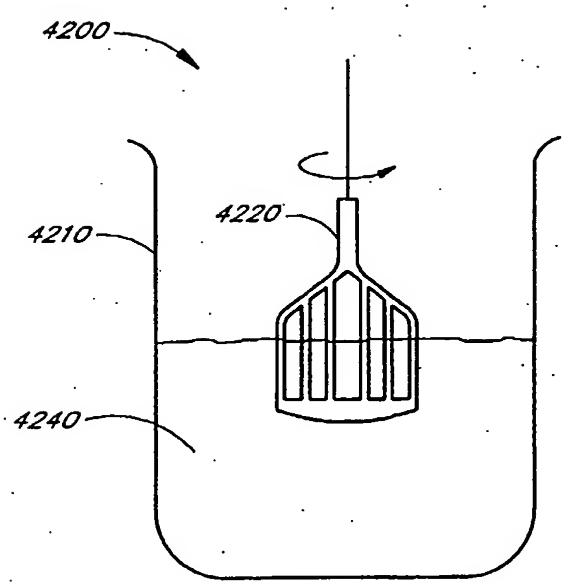


FIG. 17A

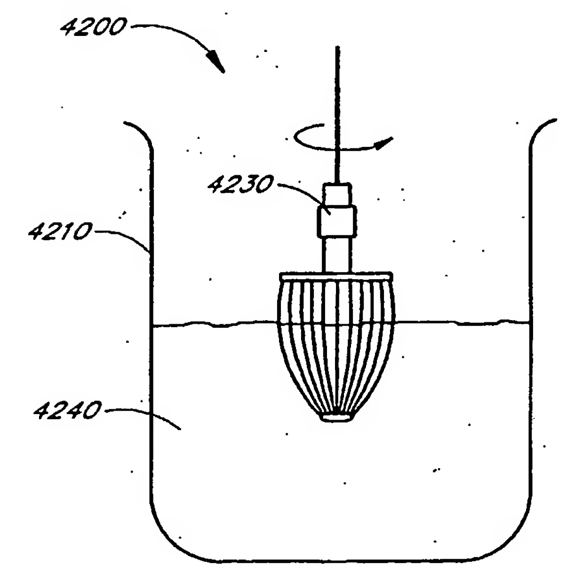


FIG. 17B

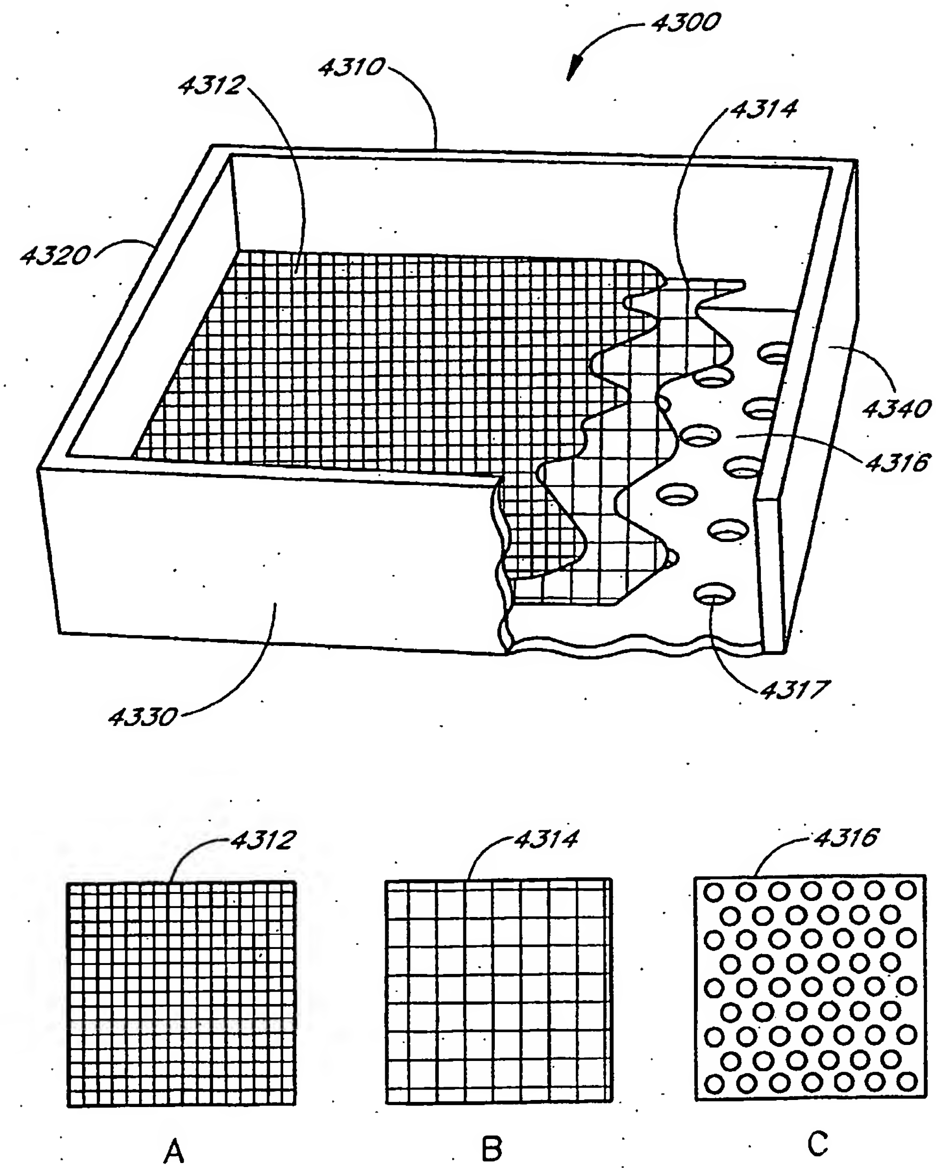

4300
4310
4312
4314
4320
4340
4316
4317
4330
4312
4314
4316
A
B
C

FIG. 18

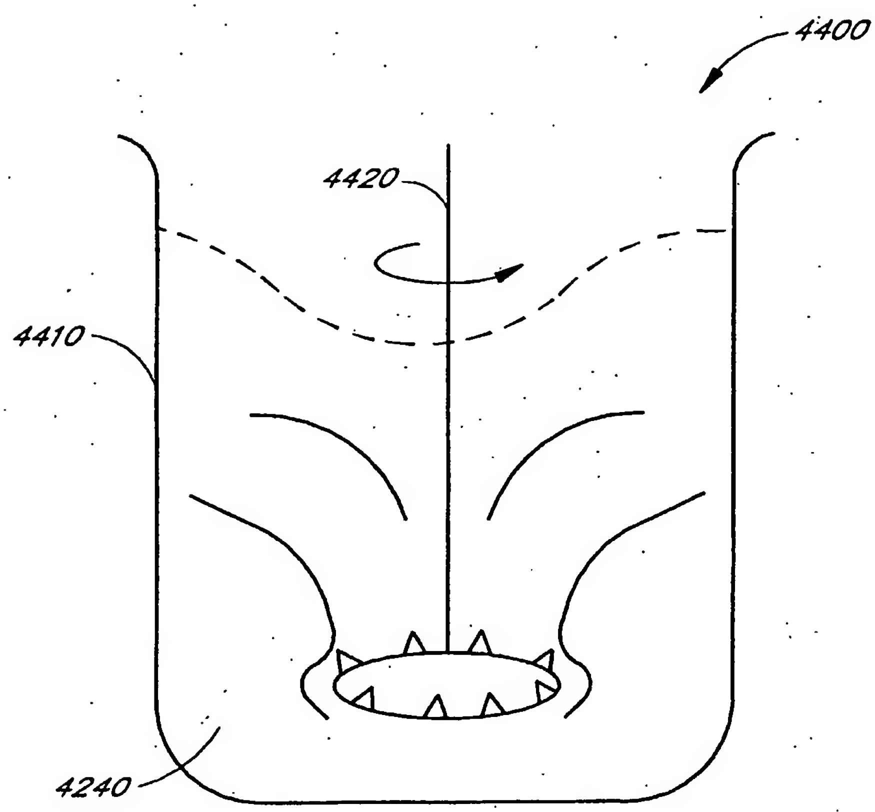


FIG. 19

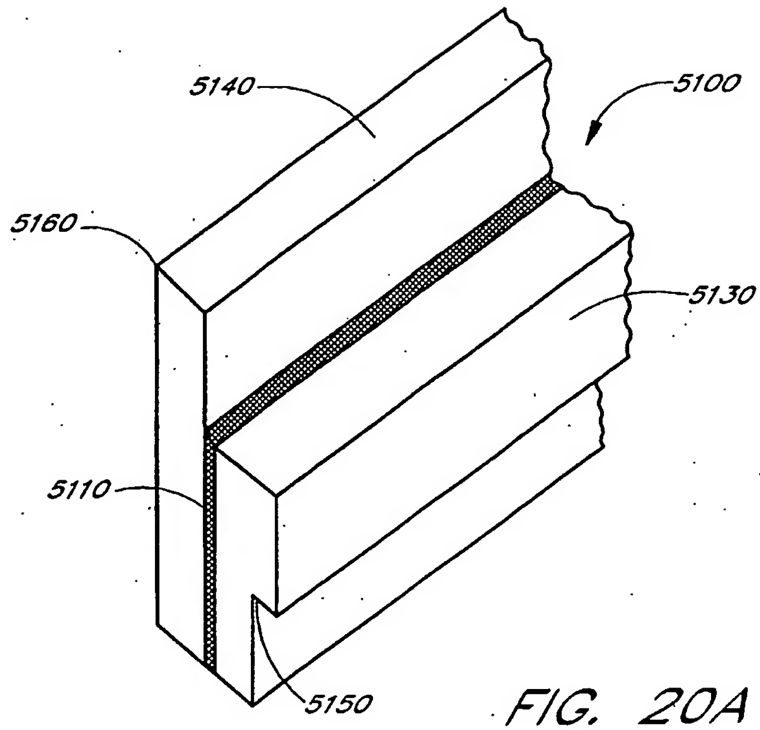


FIG. 20A

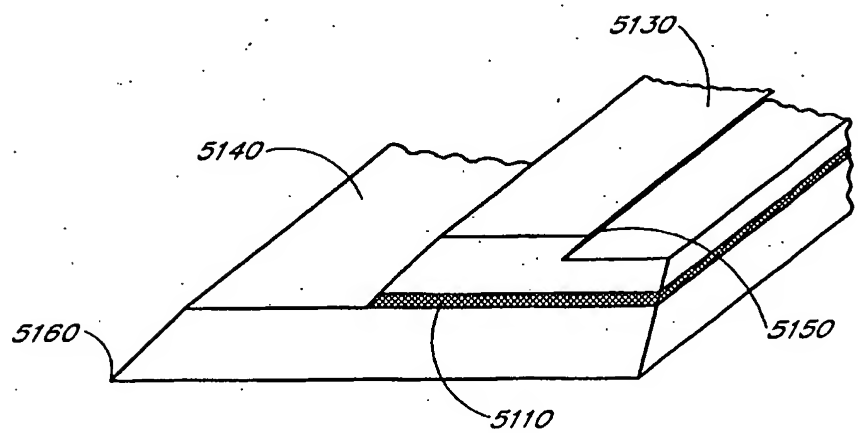


FIG. 20B

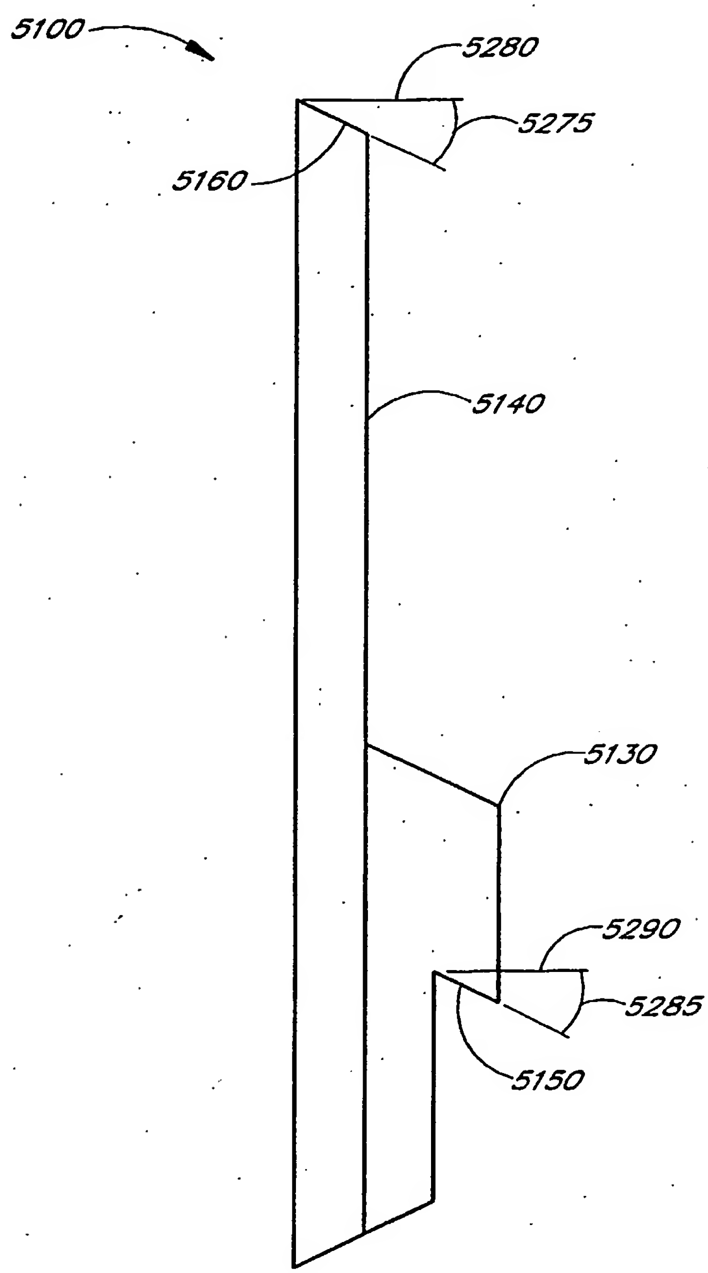


FIG. 21

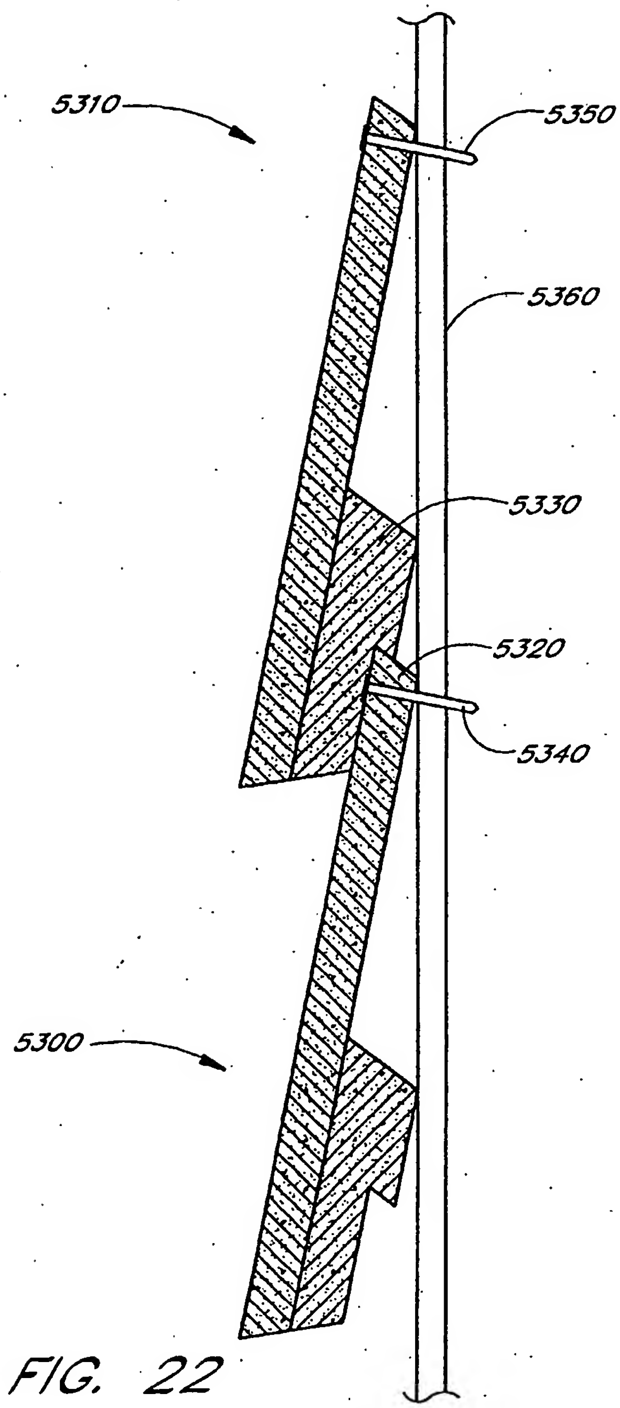


FIG. 22

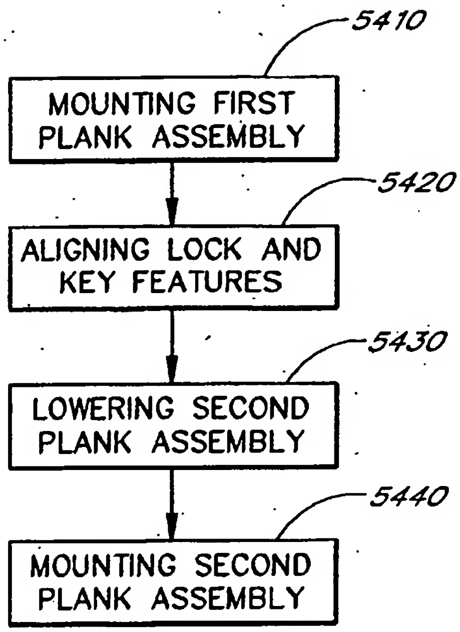

5410
MOUNTING FIRST PLANK ASSEMBLY
5420
ALIGNING LOCK AND KEY FEATURES
5430
LOWERING SECOND PLANK ASSEMBLY
5440
MOUNTING SECOND PLANK ASSEMBLY

FIG. 23

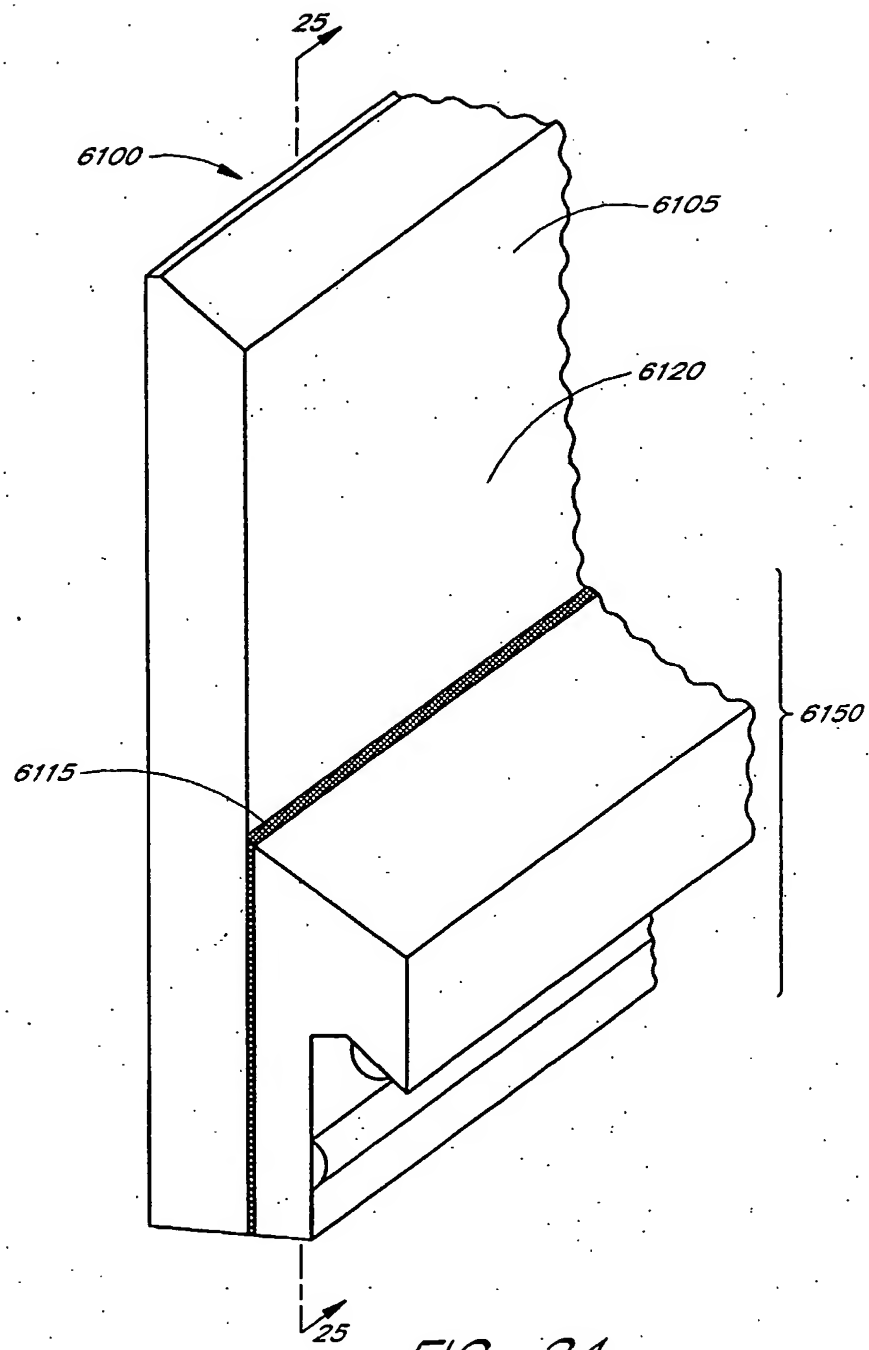


FIG. 24

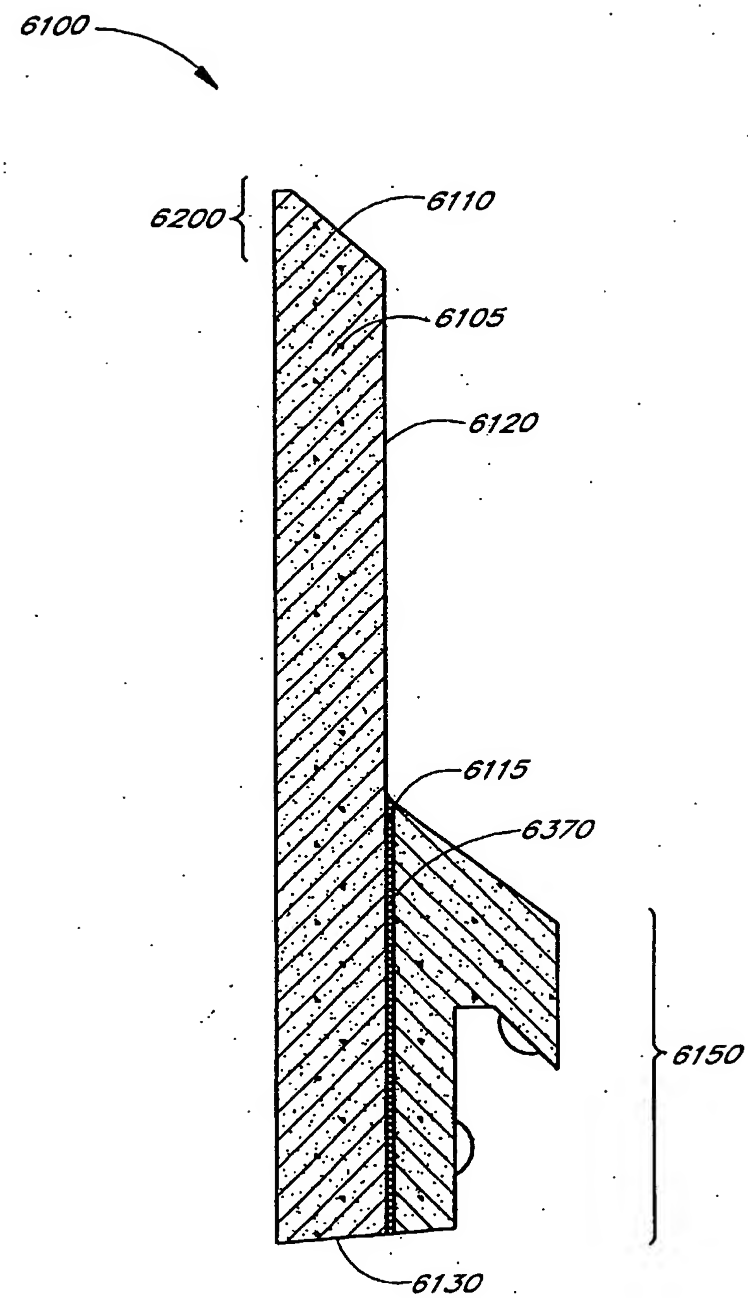


FIG. 25

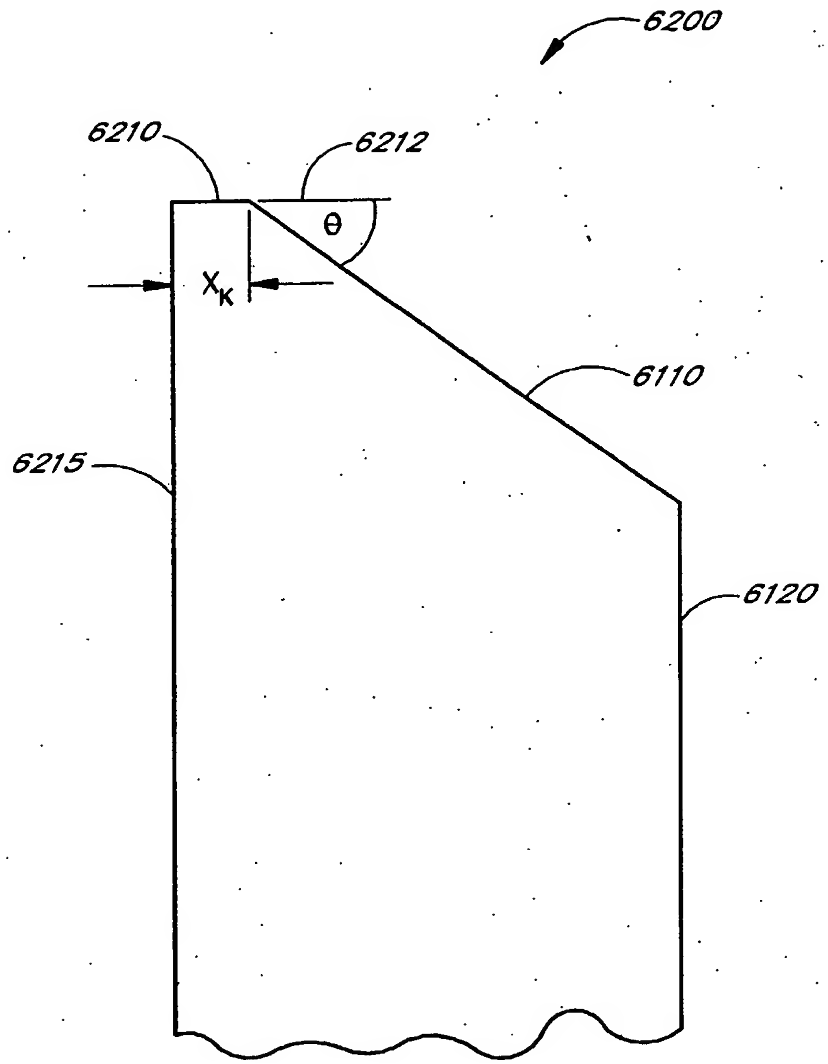


FIG. 26

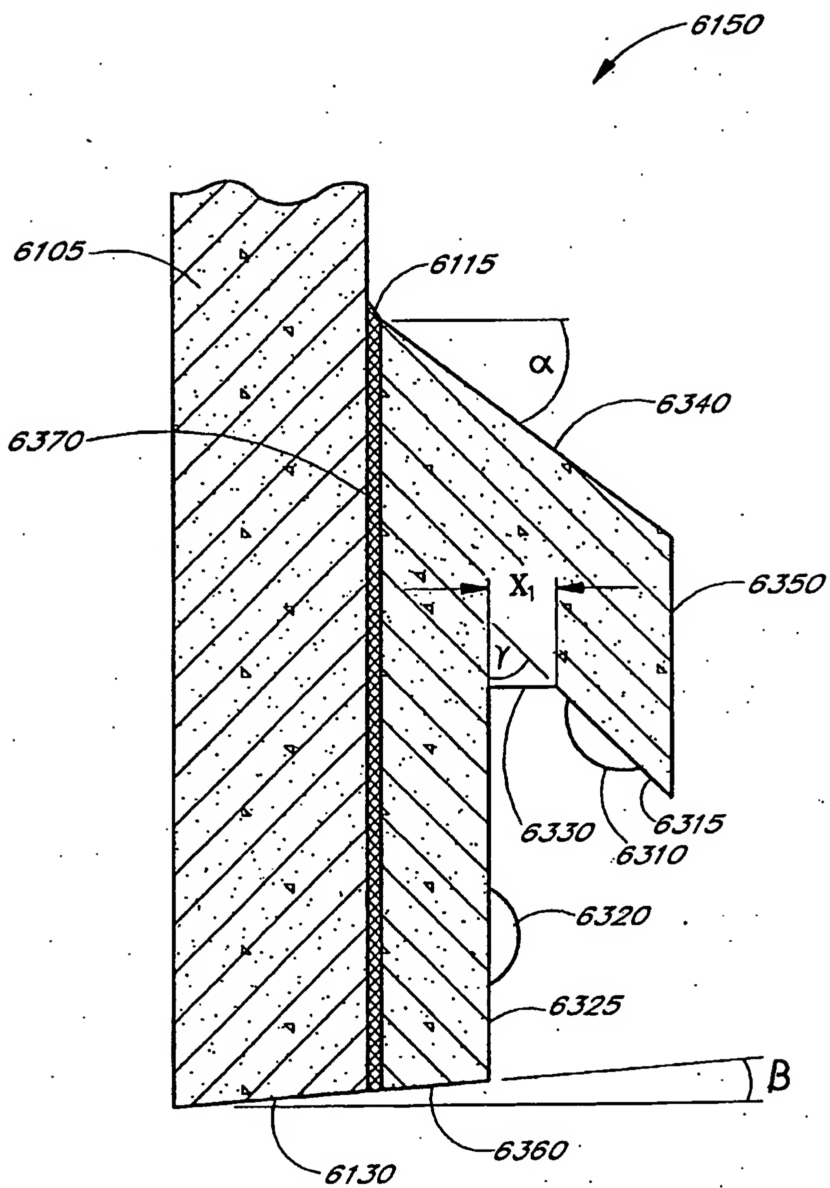

6150
6105
6115
α
6340
6370
6350
X_1
γ
6330
6315
6310
6320
6325
β
6130
6360

FIG. 27

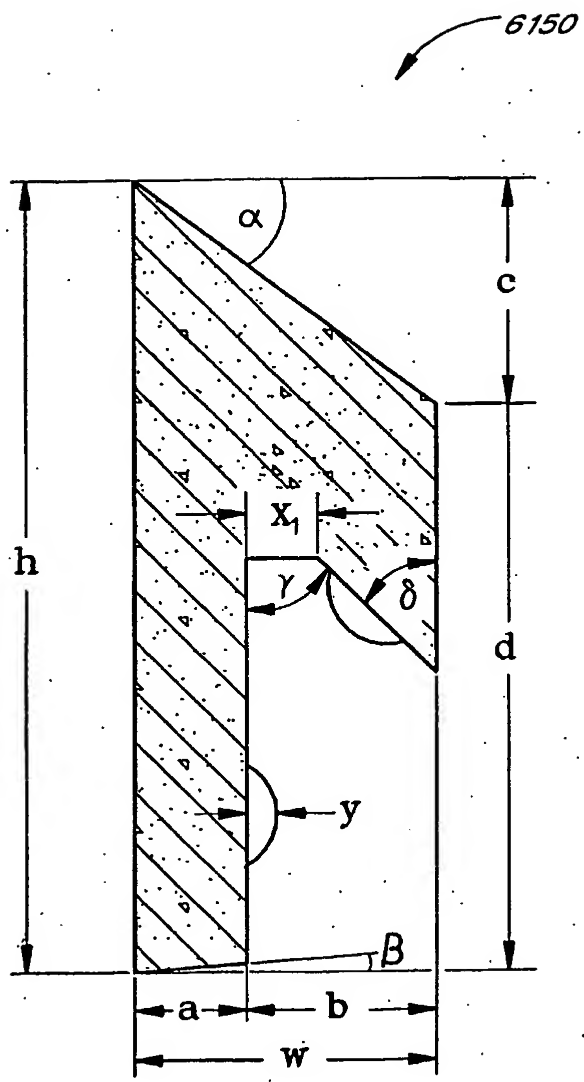


FIG. 28

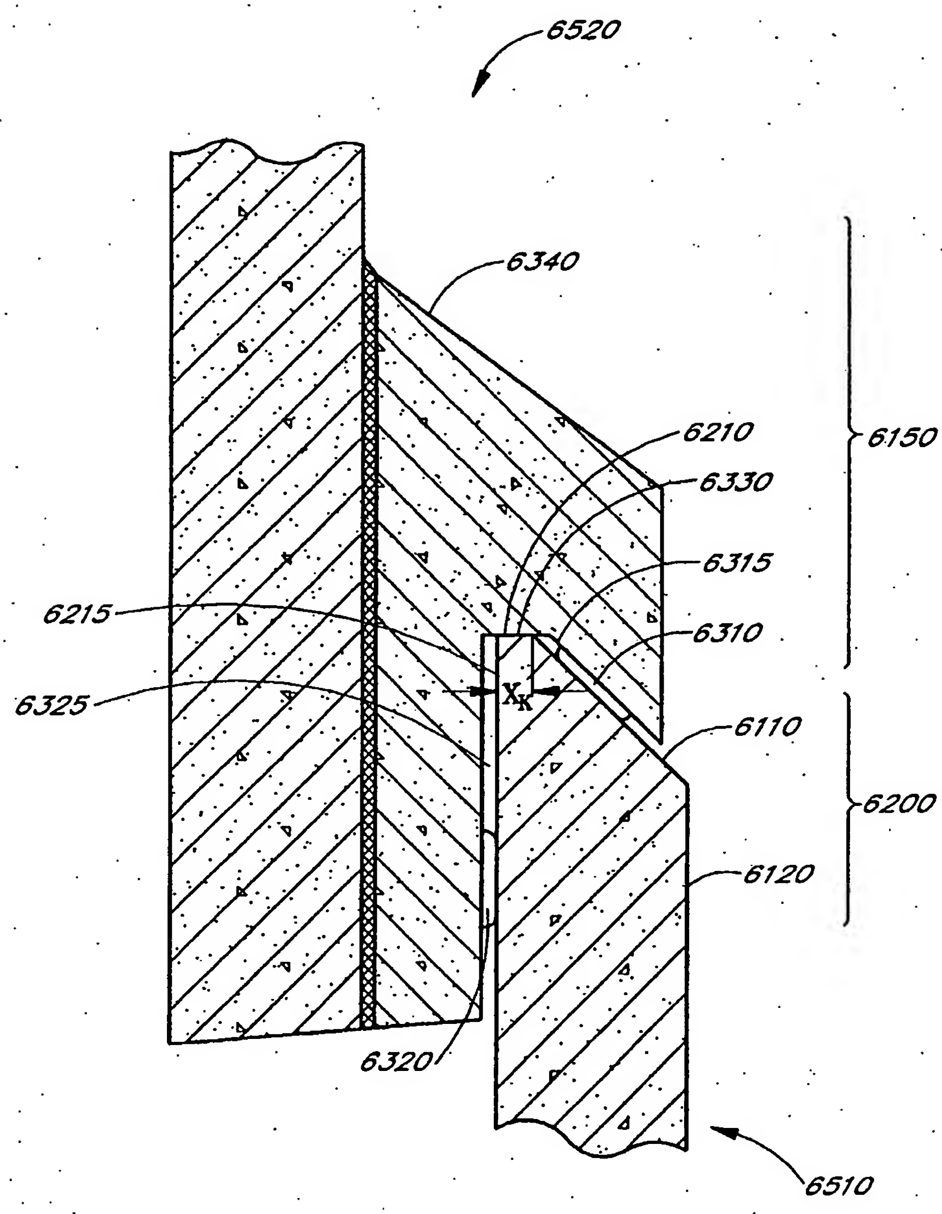

6520
6340
6210
6330
6315
6310
6150
6215
6325
X_K
6110
6200
6120
6320
6510

FIG. 29

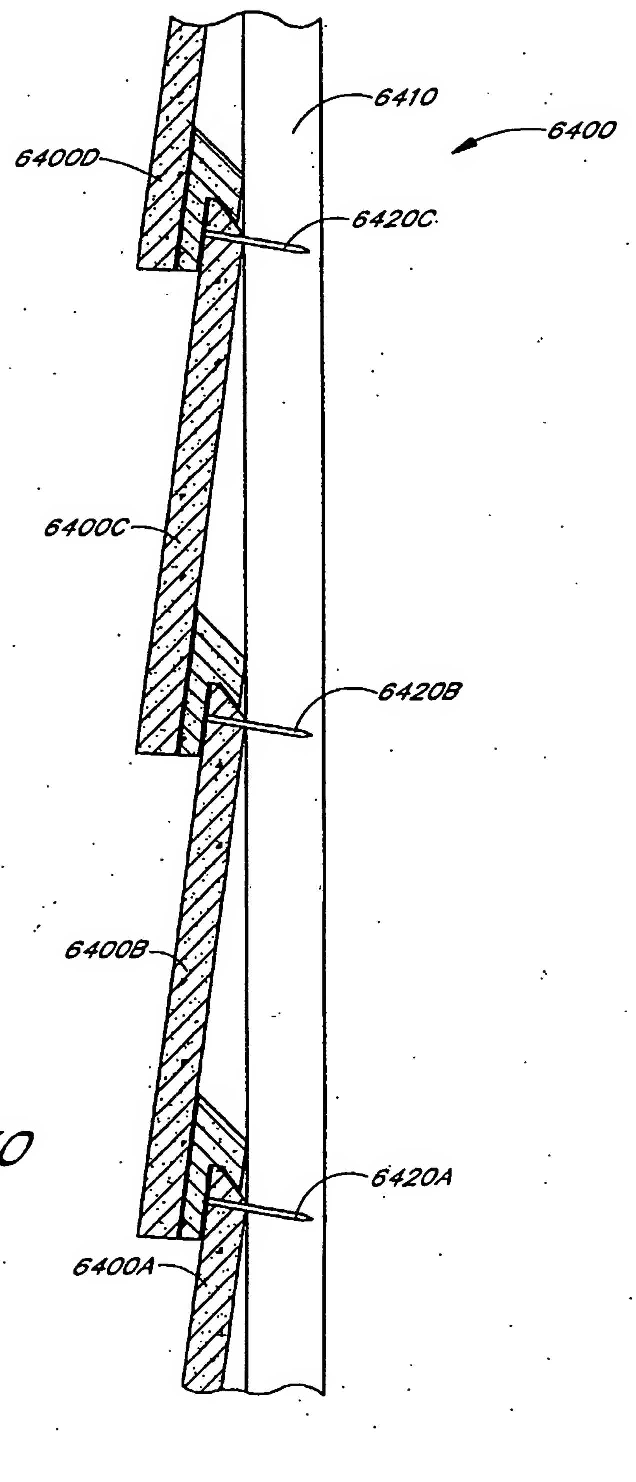


FIG. 30

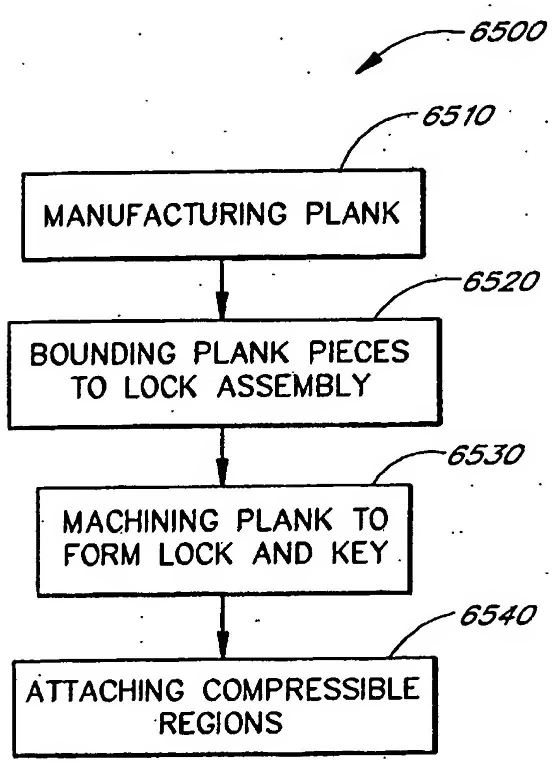

6500
6510
MANUFACTURING PLANK
6520
BOUNDING PLANK PIECES TO LOCK ASSEMBLY
6530
MACHINING PLANK TO FORM LOCK AND KEY
6540
ATTACHING COMPRESSIBLE REGIONS

FIG. 31

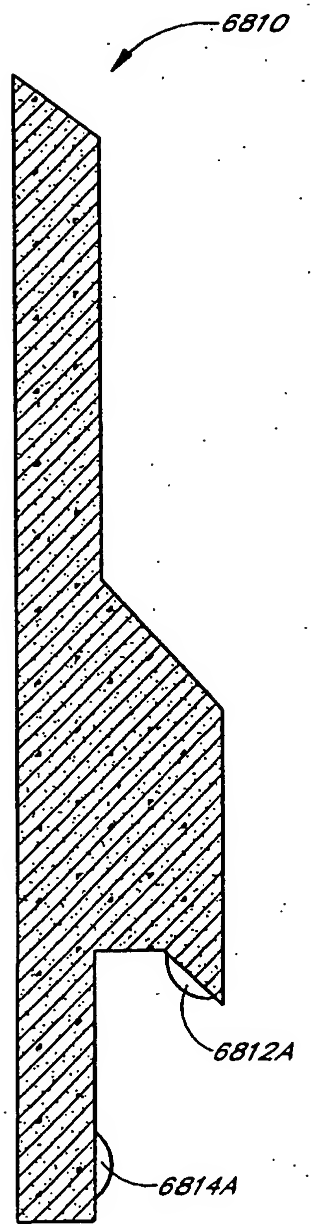


FIG. 32A

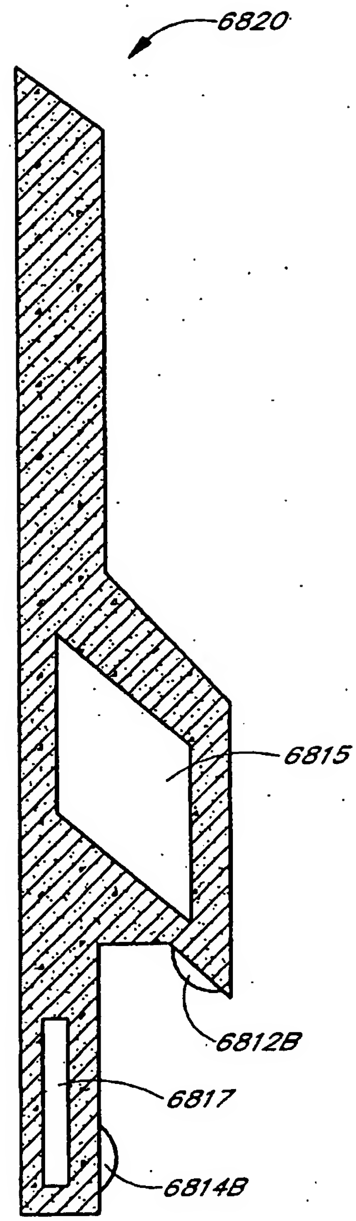


FIG. 32B

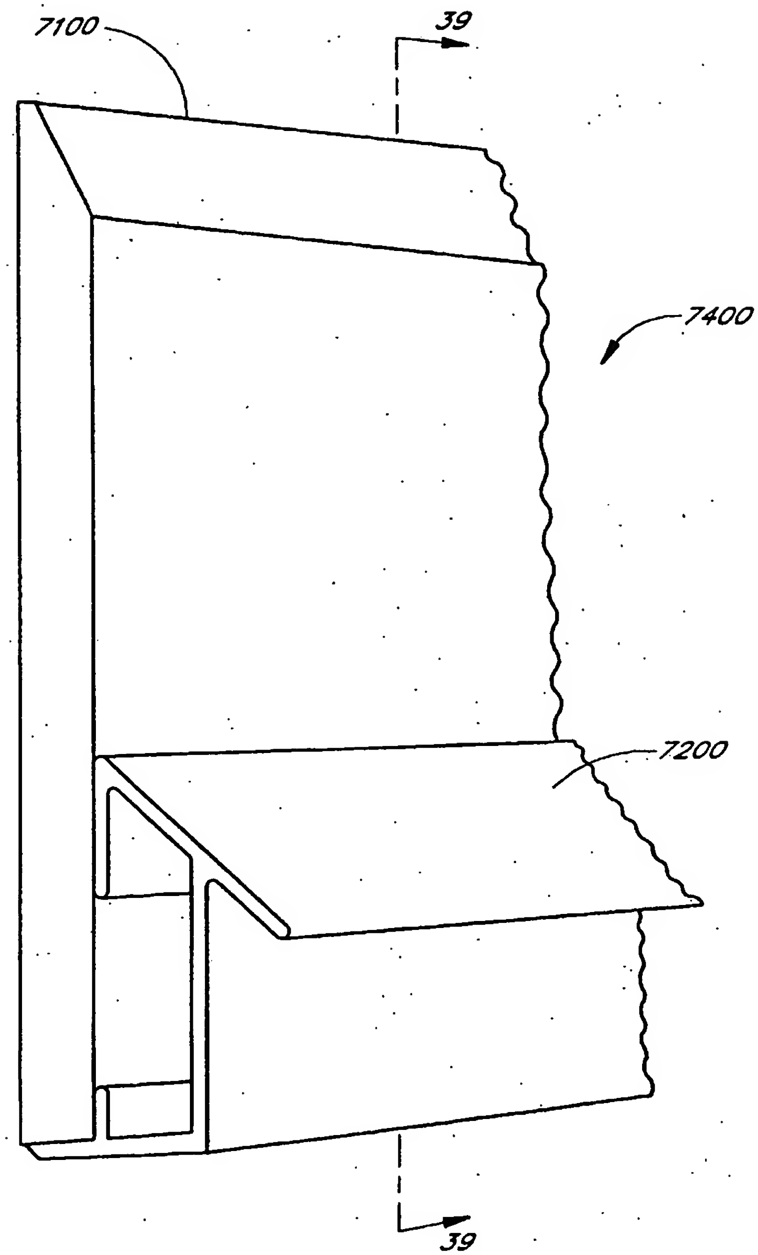


FIG. 33

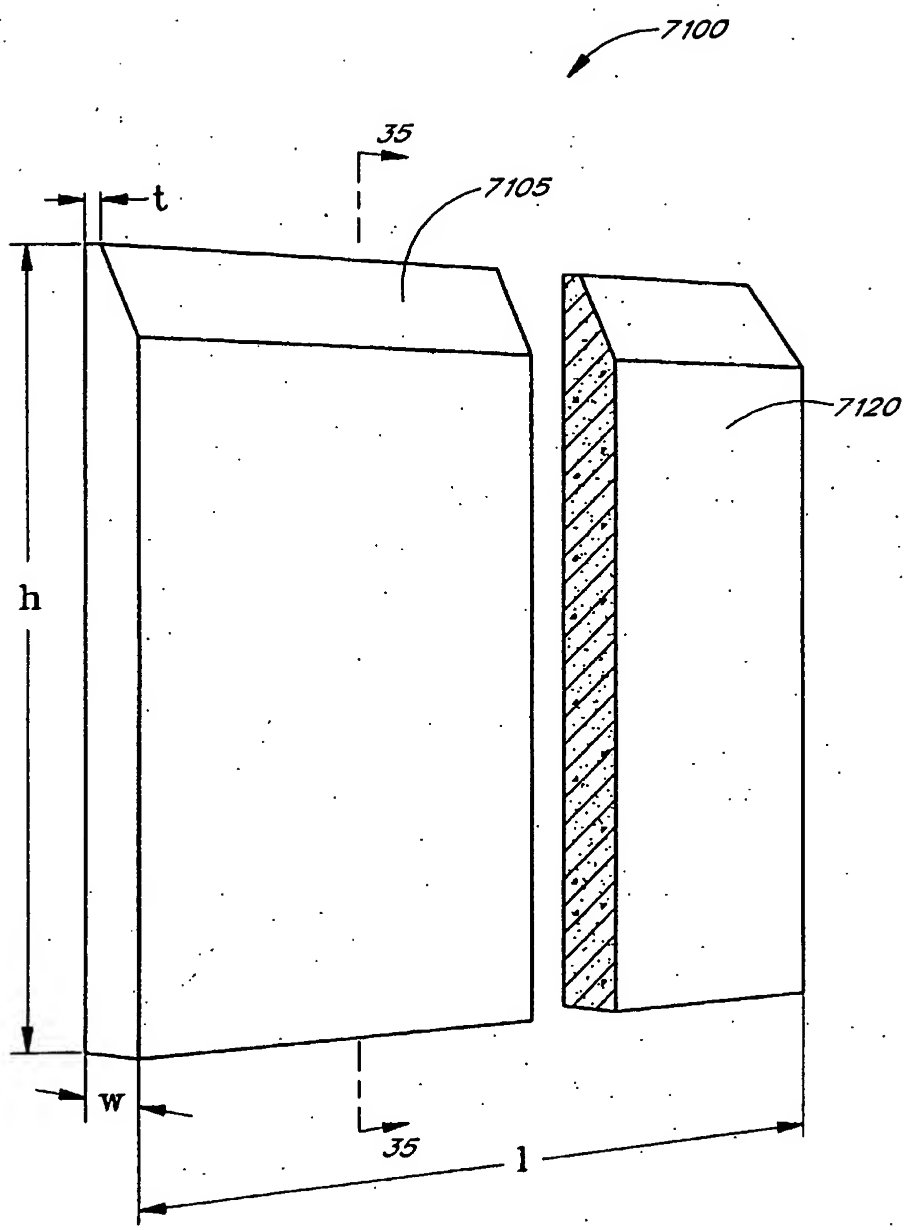


FIG. 34

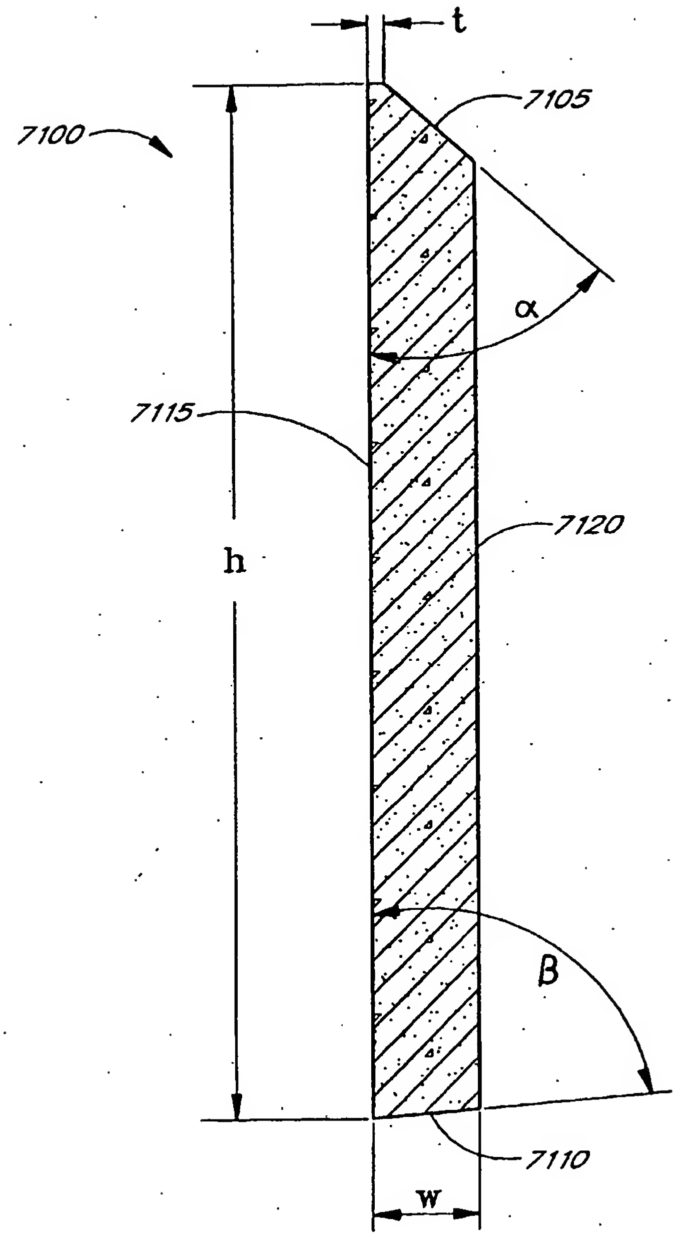


FIG. 35

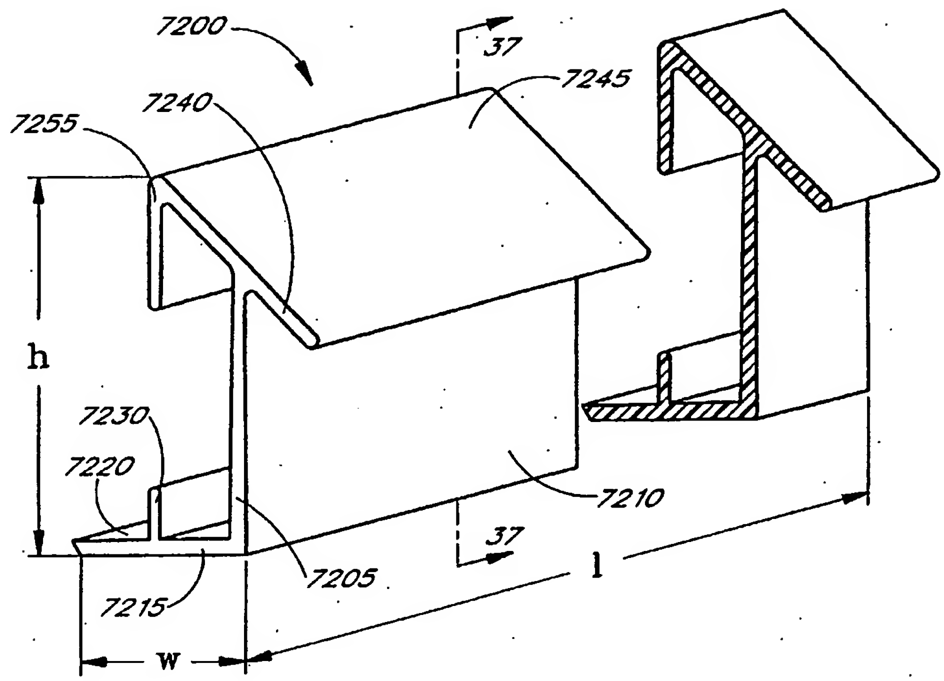


FIG. 36

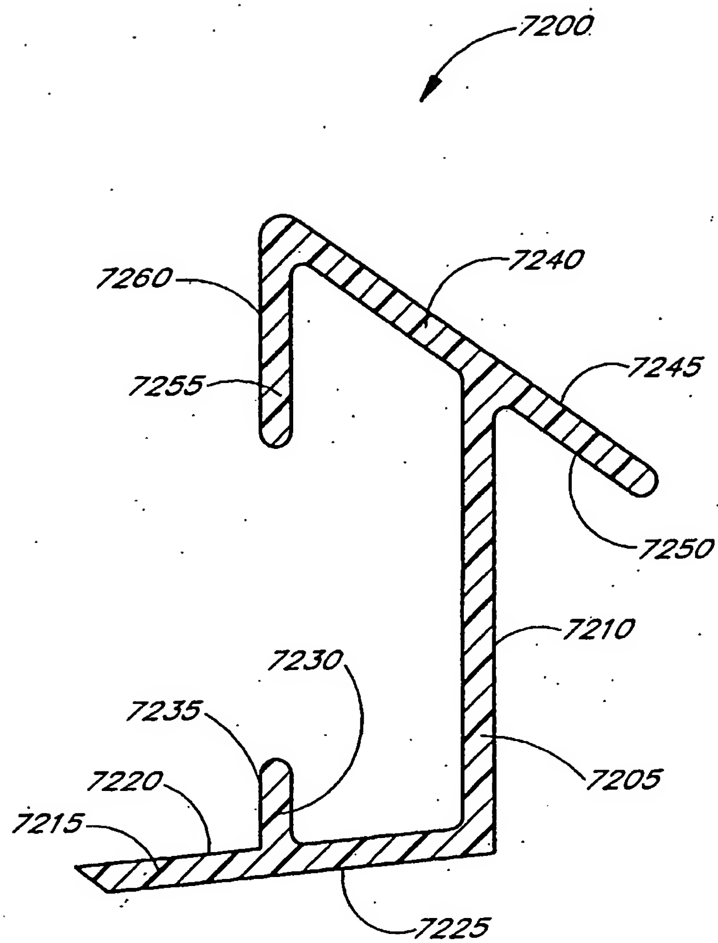

7200
7260
7240
7255
7245
7250
7210
7230
7235
7205
7220
7215
7225

FIG. 37

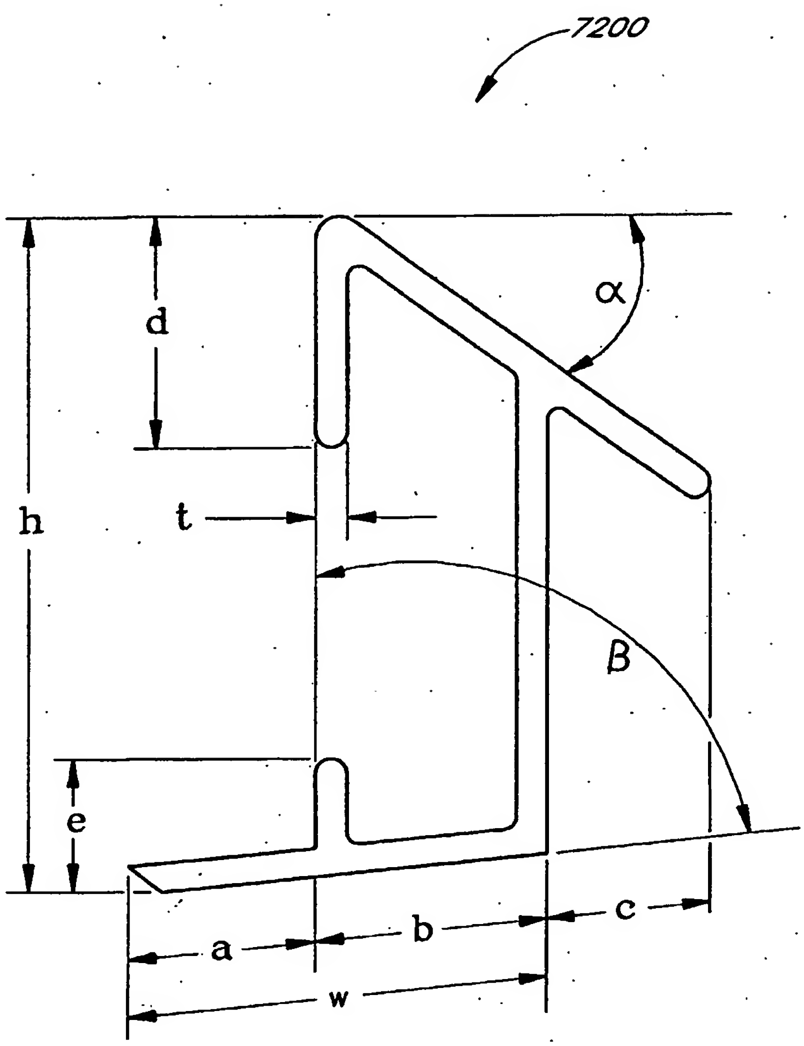


FIG. 38

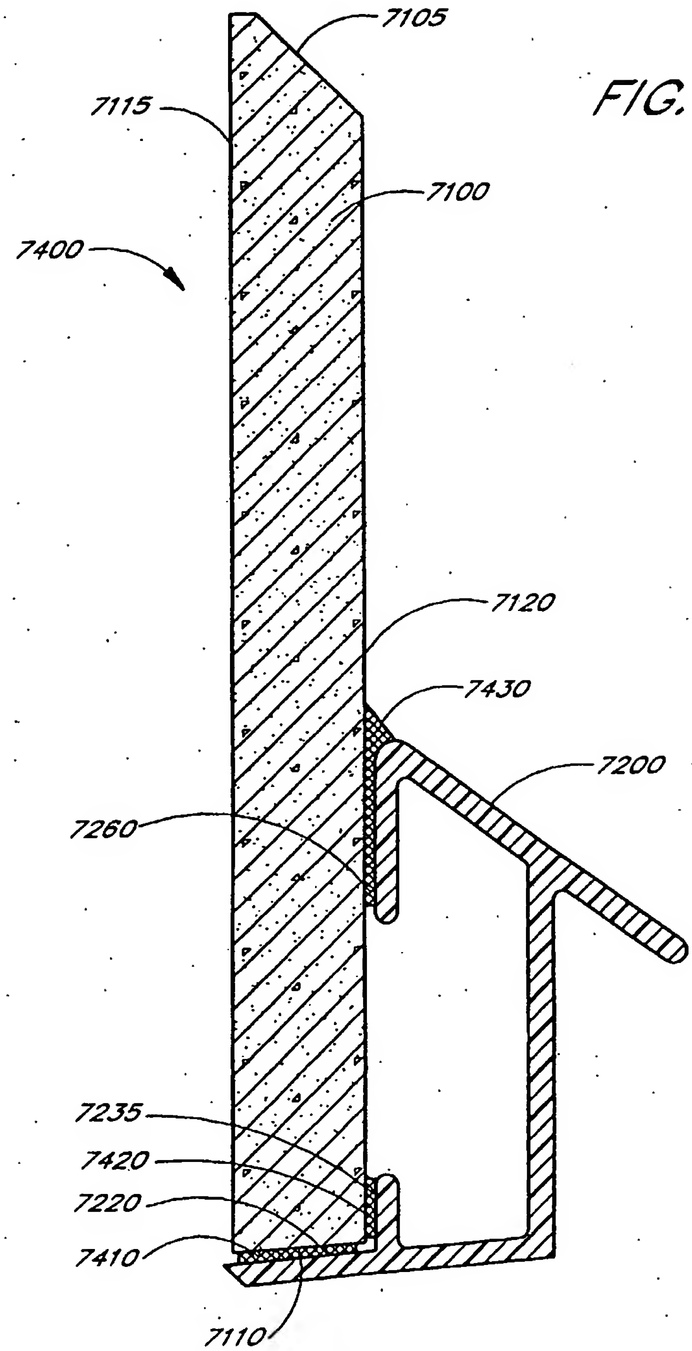

7105
7115
7100
7400
7120
7430
7200
7260
7235
7420
7220
7410
7110

FIG. 39

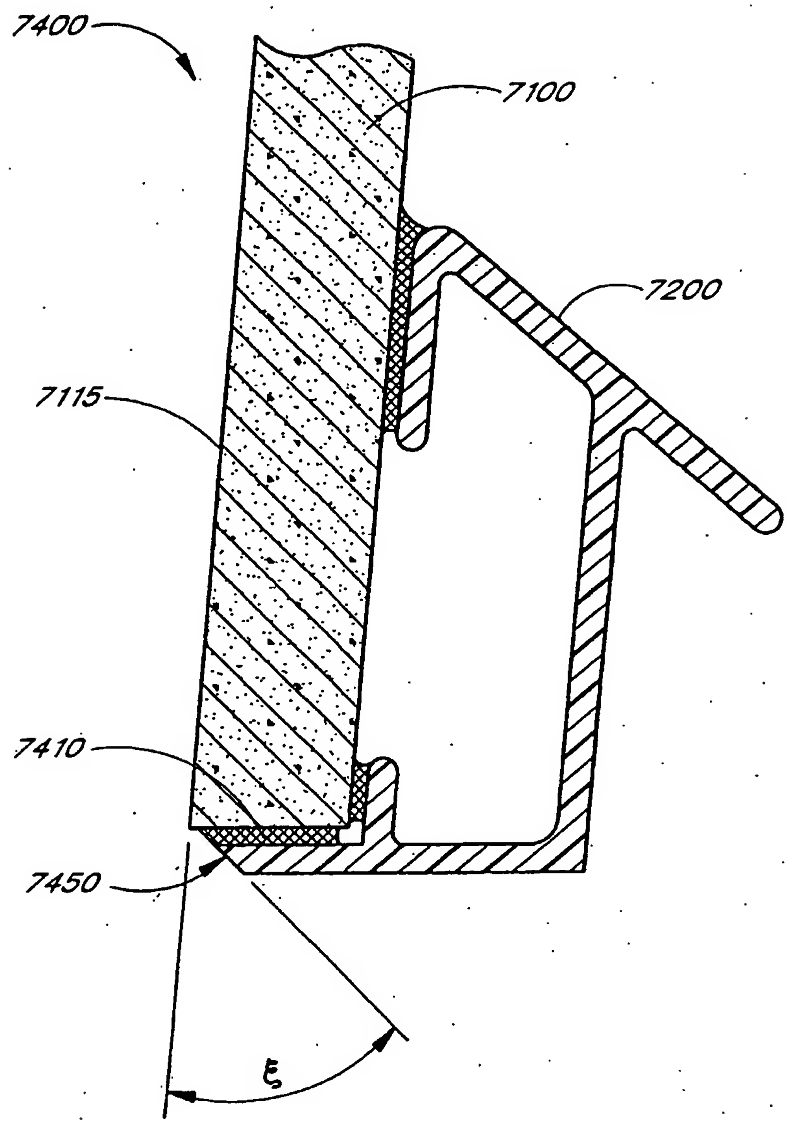


FIG. 40

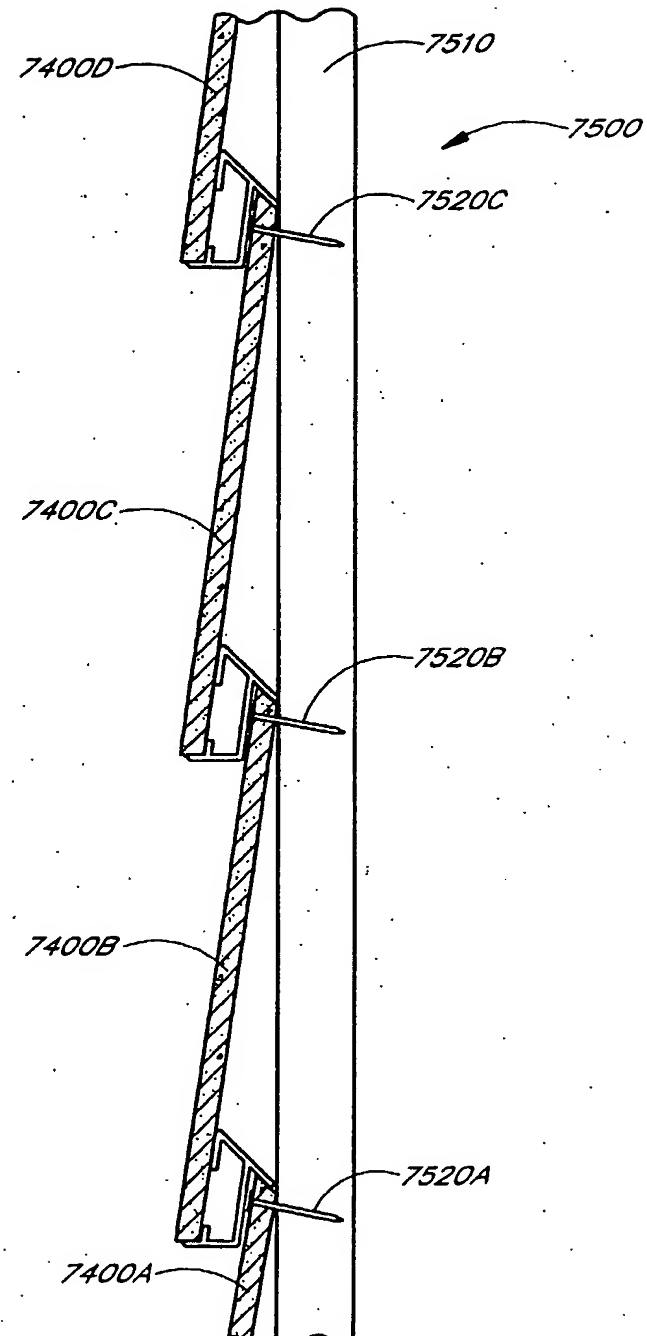


FIG. 41

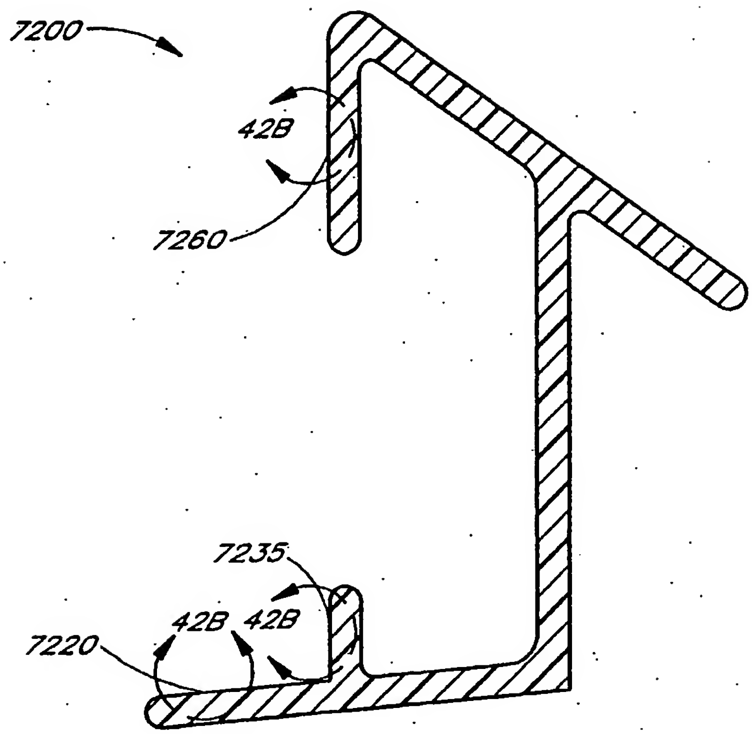


FIG. 42A

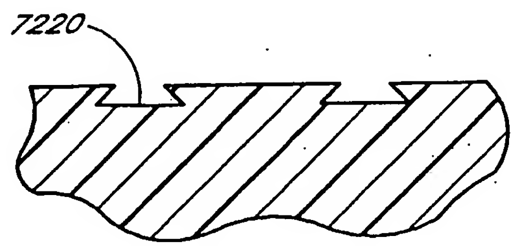


FIG. 42B

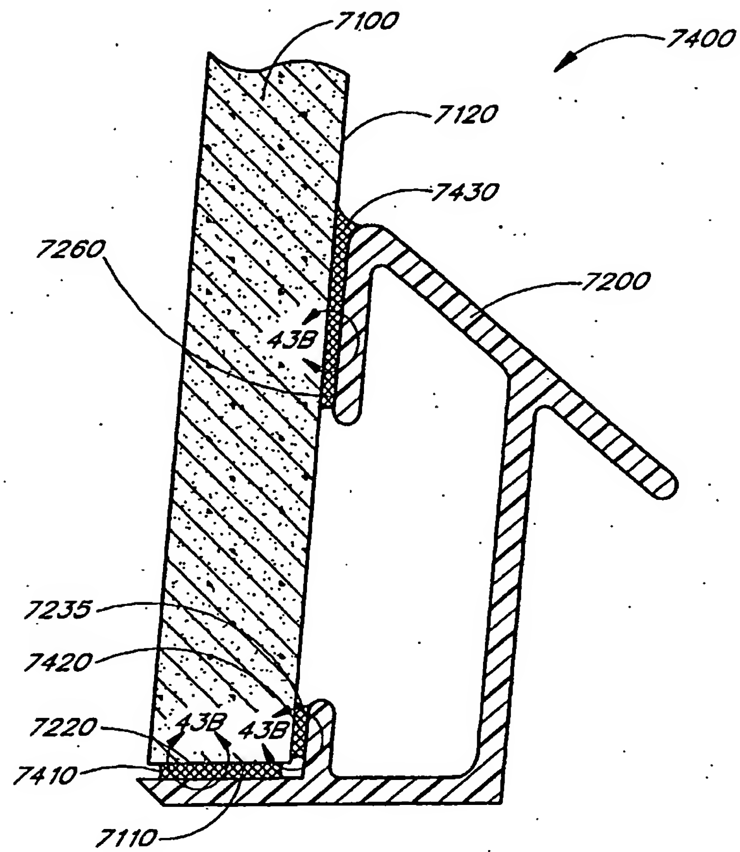


FIG. 43A

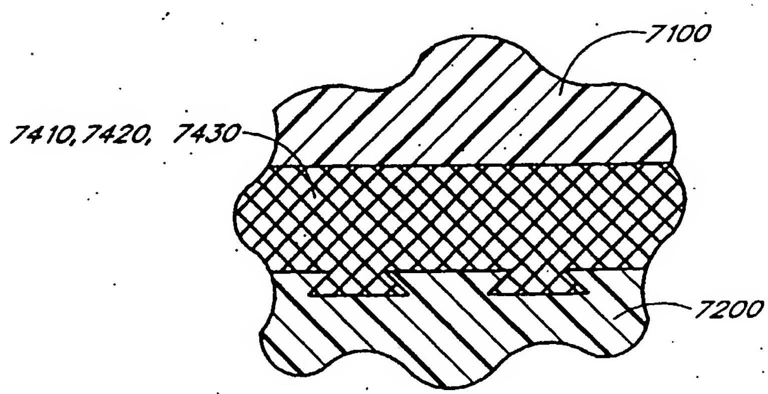


FIG. 43B

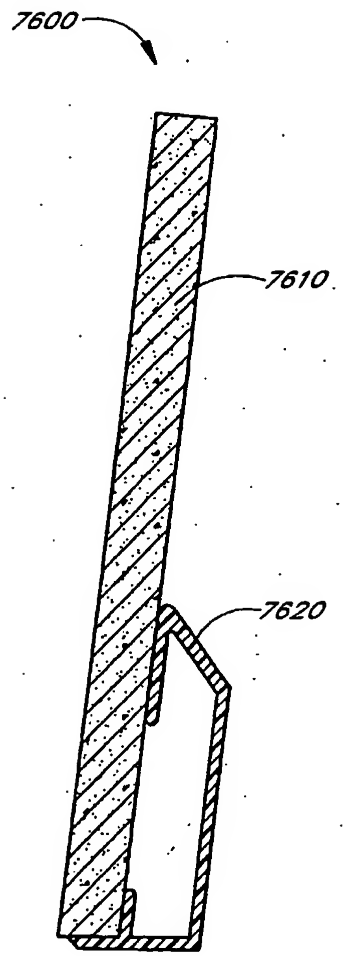


FIG. 44A

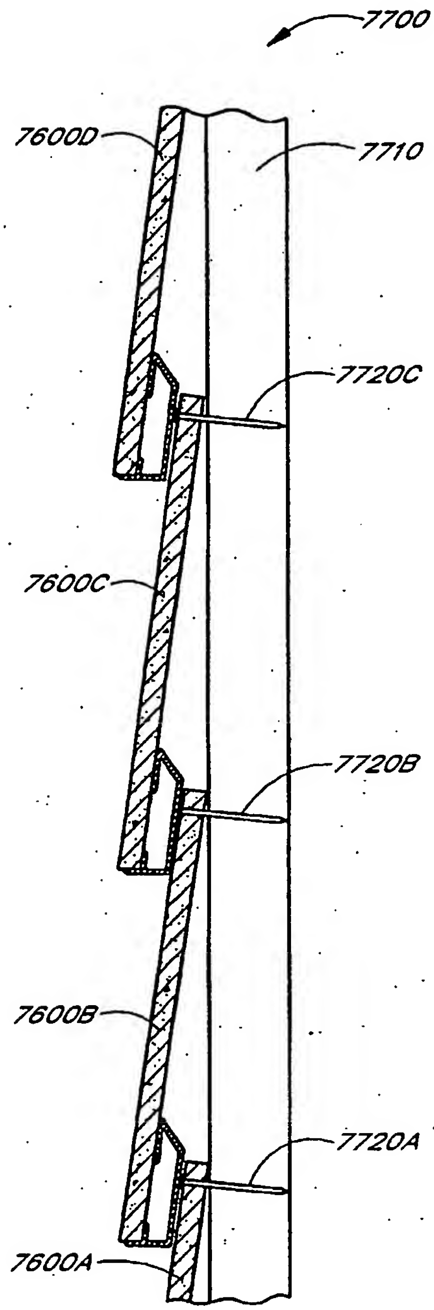


FIG. 44B

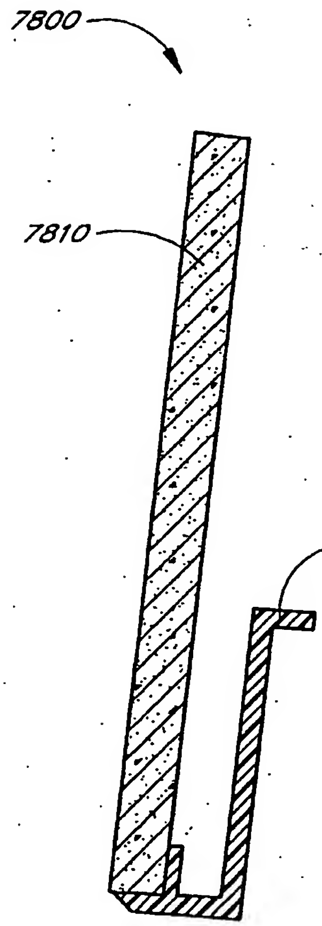


FIG. 45A

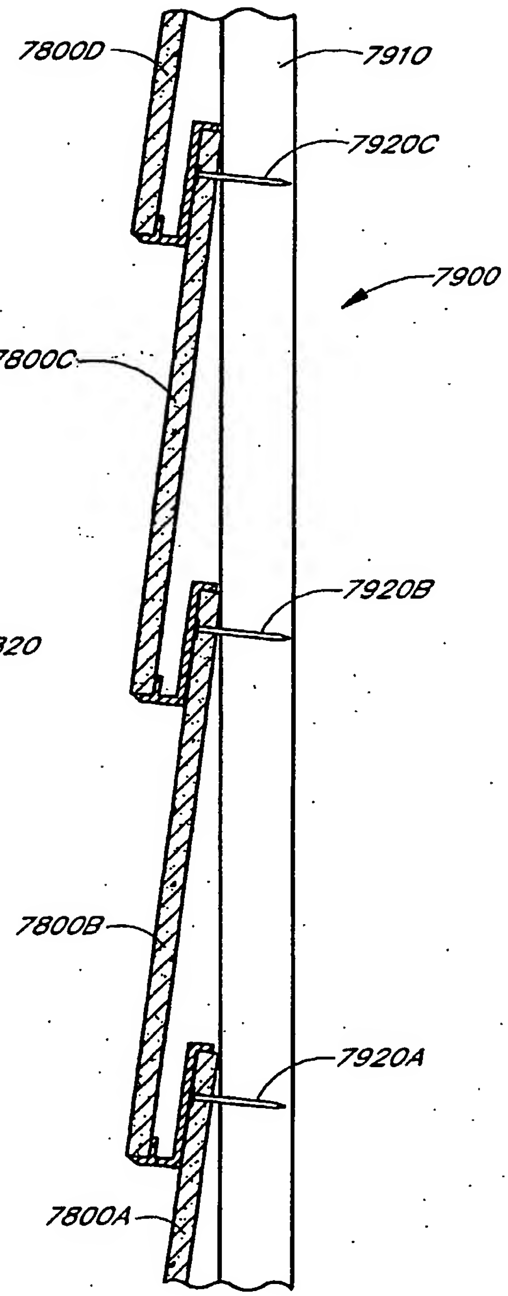
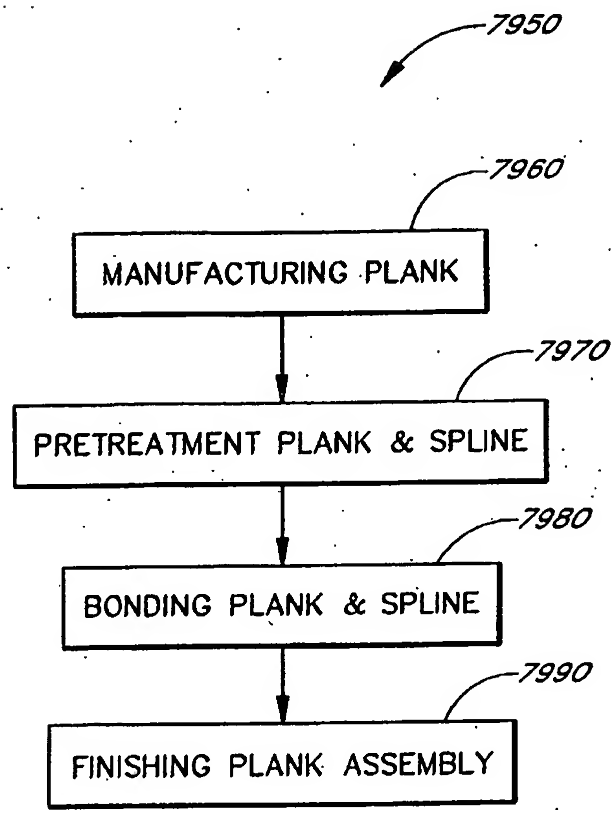


FIG. 45B


7950
7960
MANUFACTURING PLANK
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FINISHING PLANK ASSEMBLY

FIG. 46

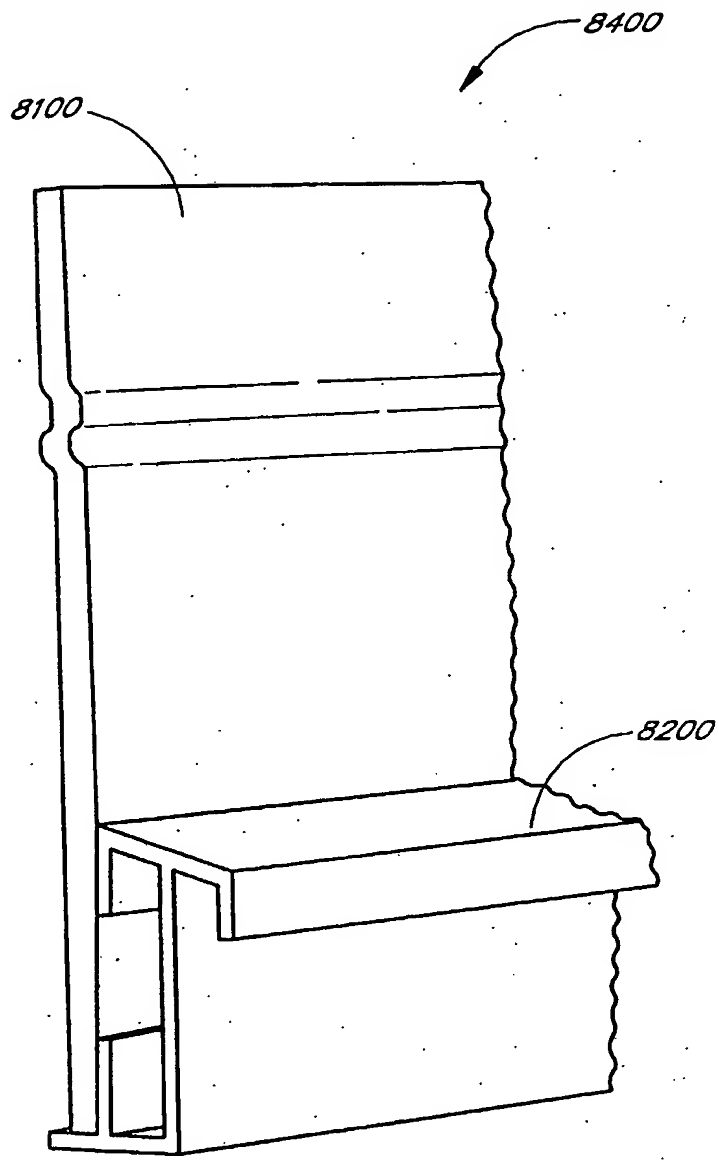

FIG. 47

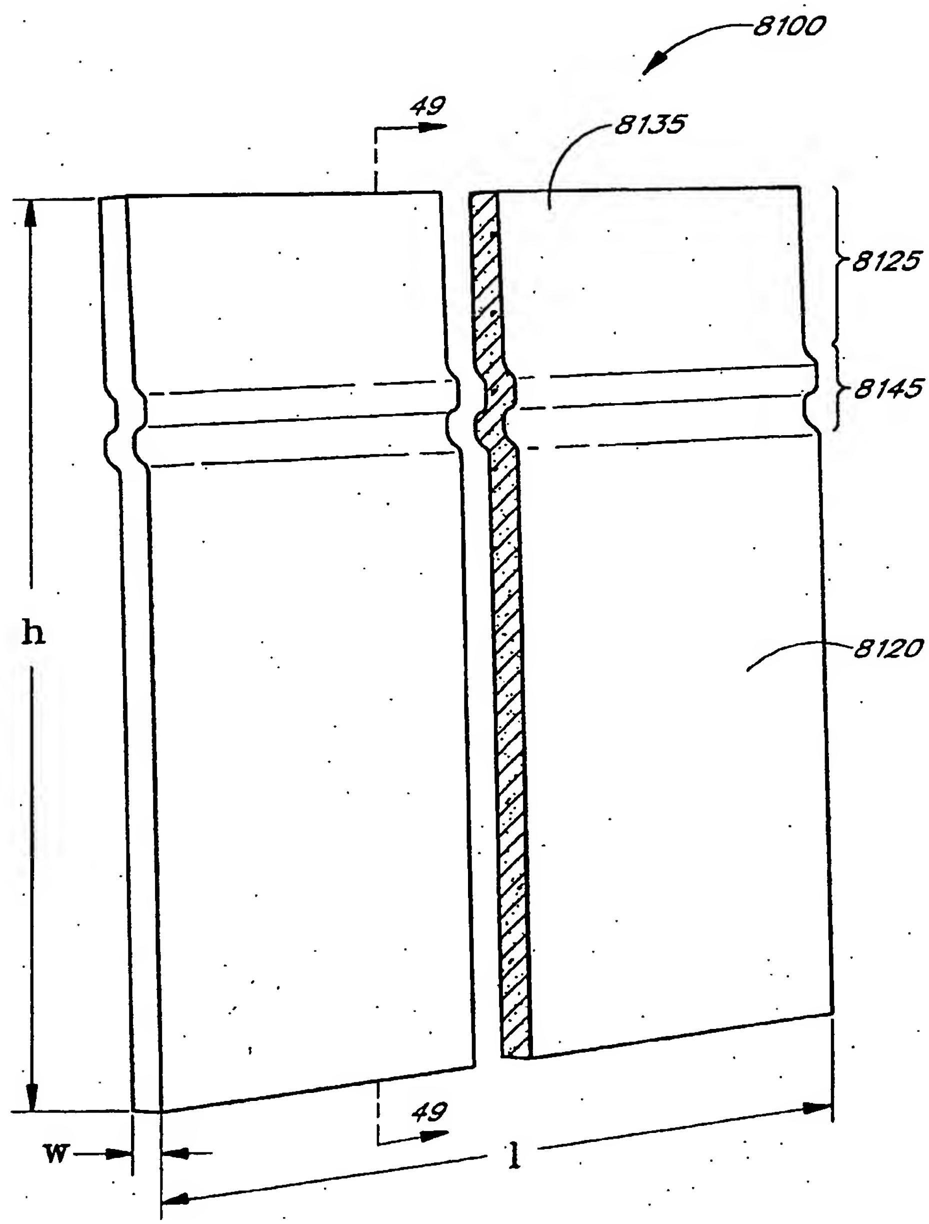

FIG. 48

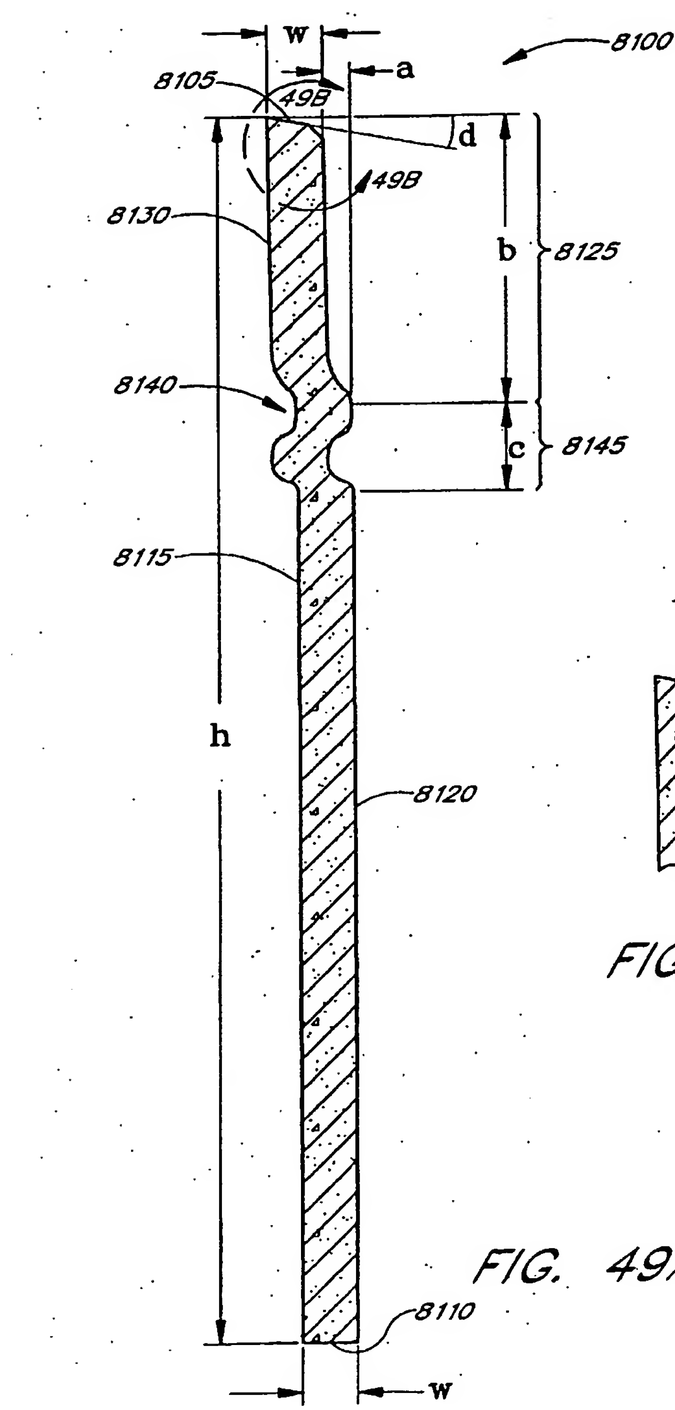

FIG. 49A

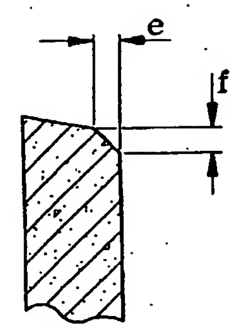

FIG. 49B

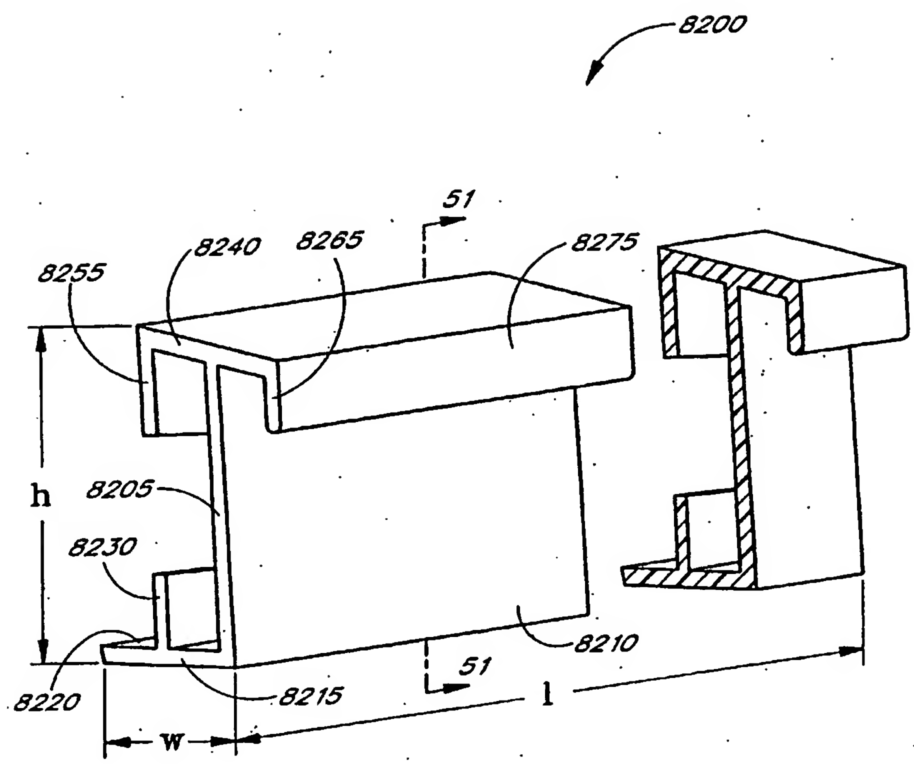

FIG. 50

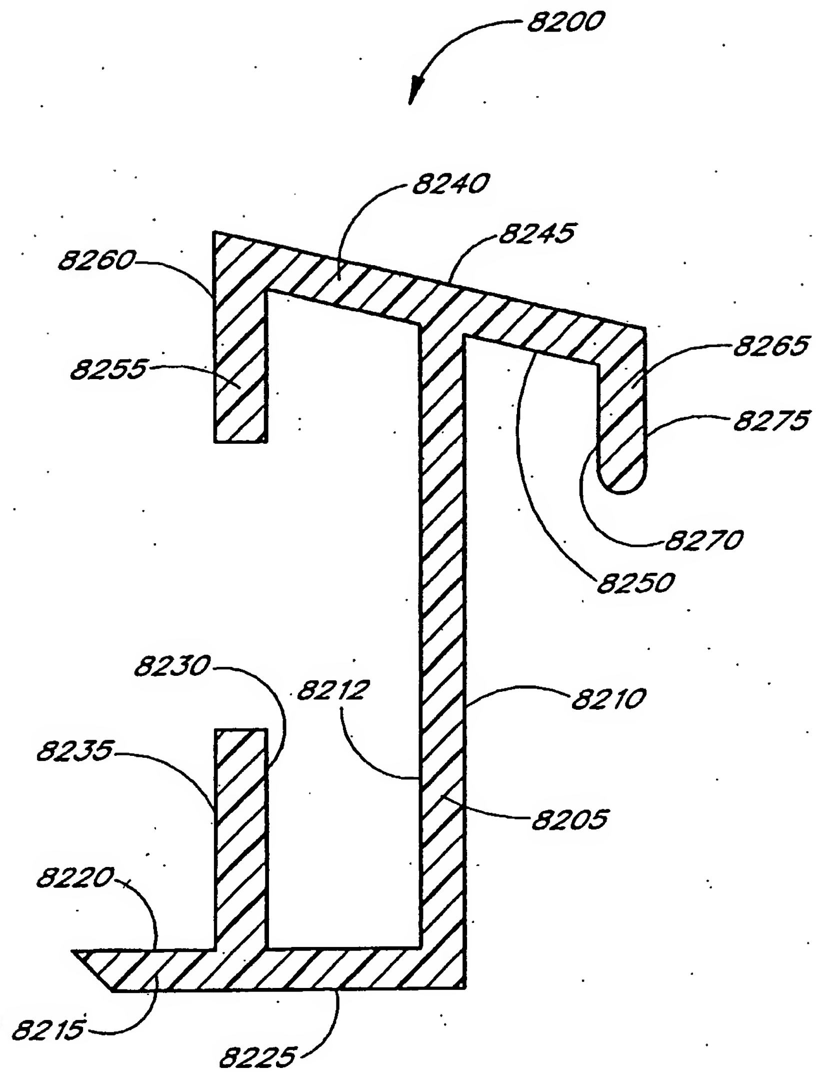
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FIG. 51

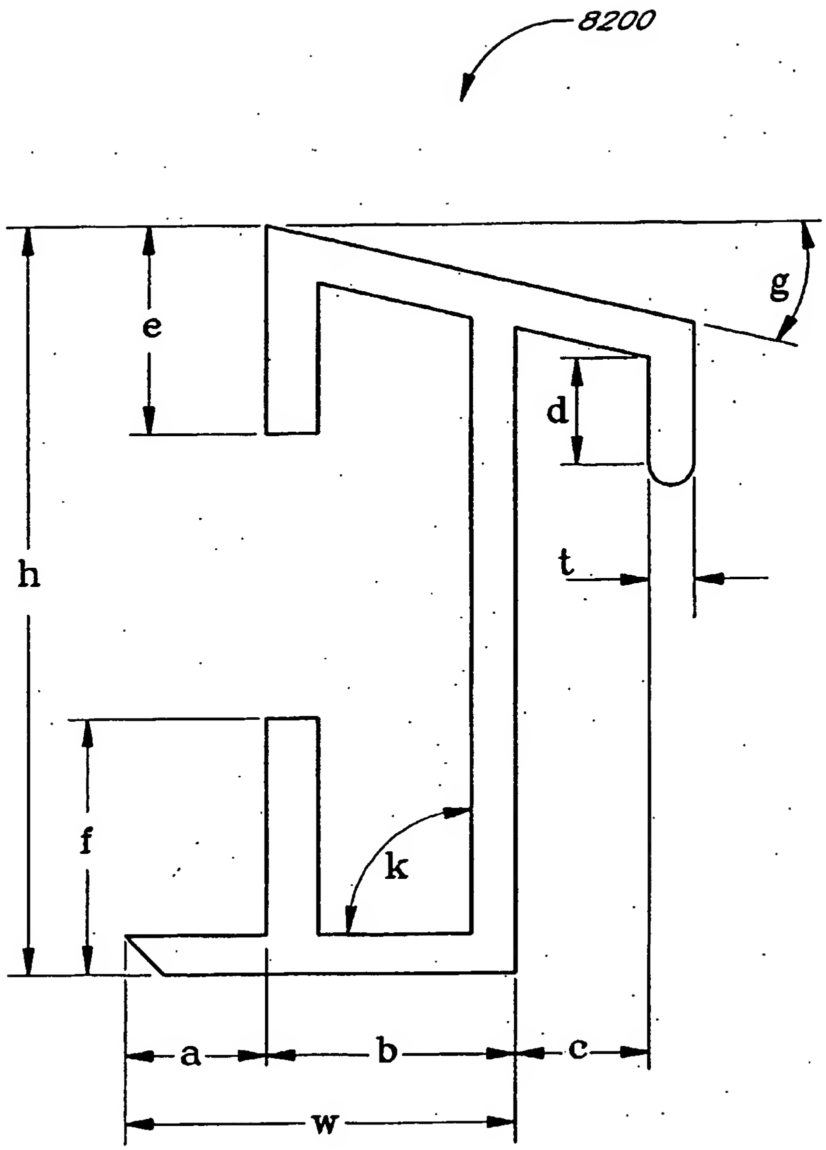


FIG. 52

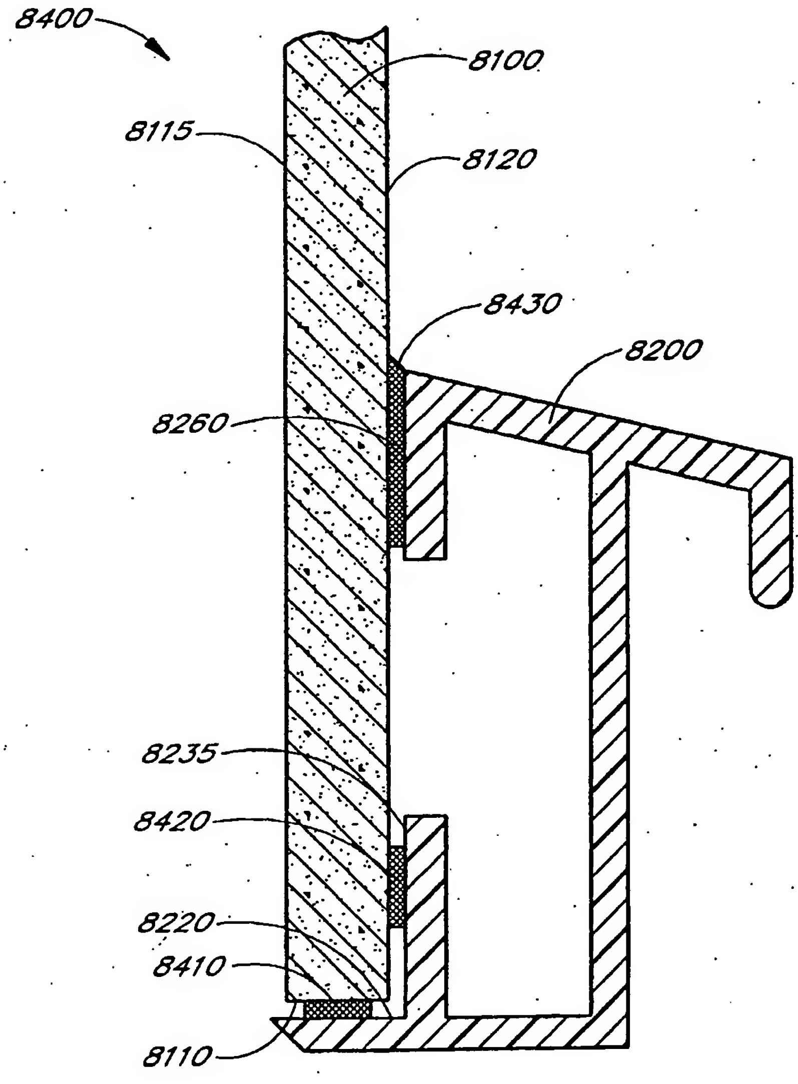


FIG. 53

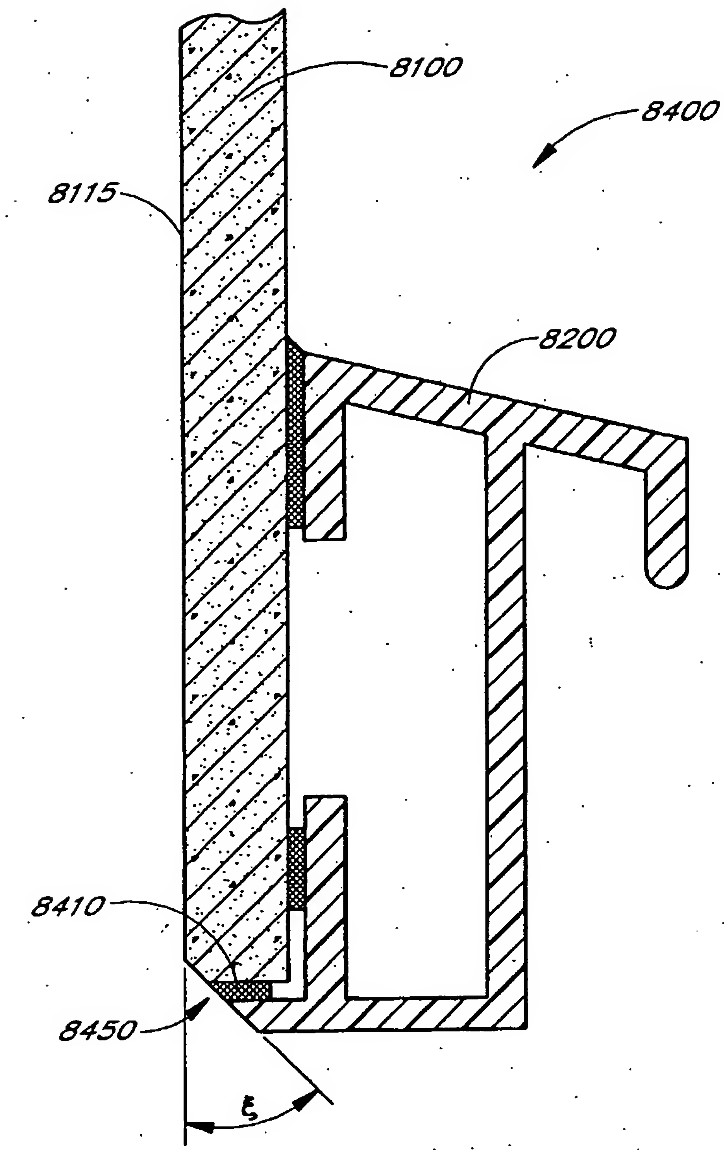


FIG. 54

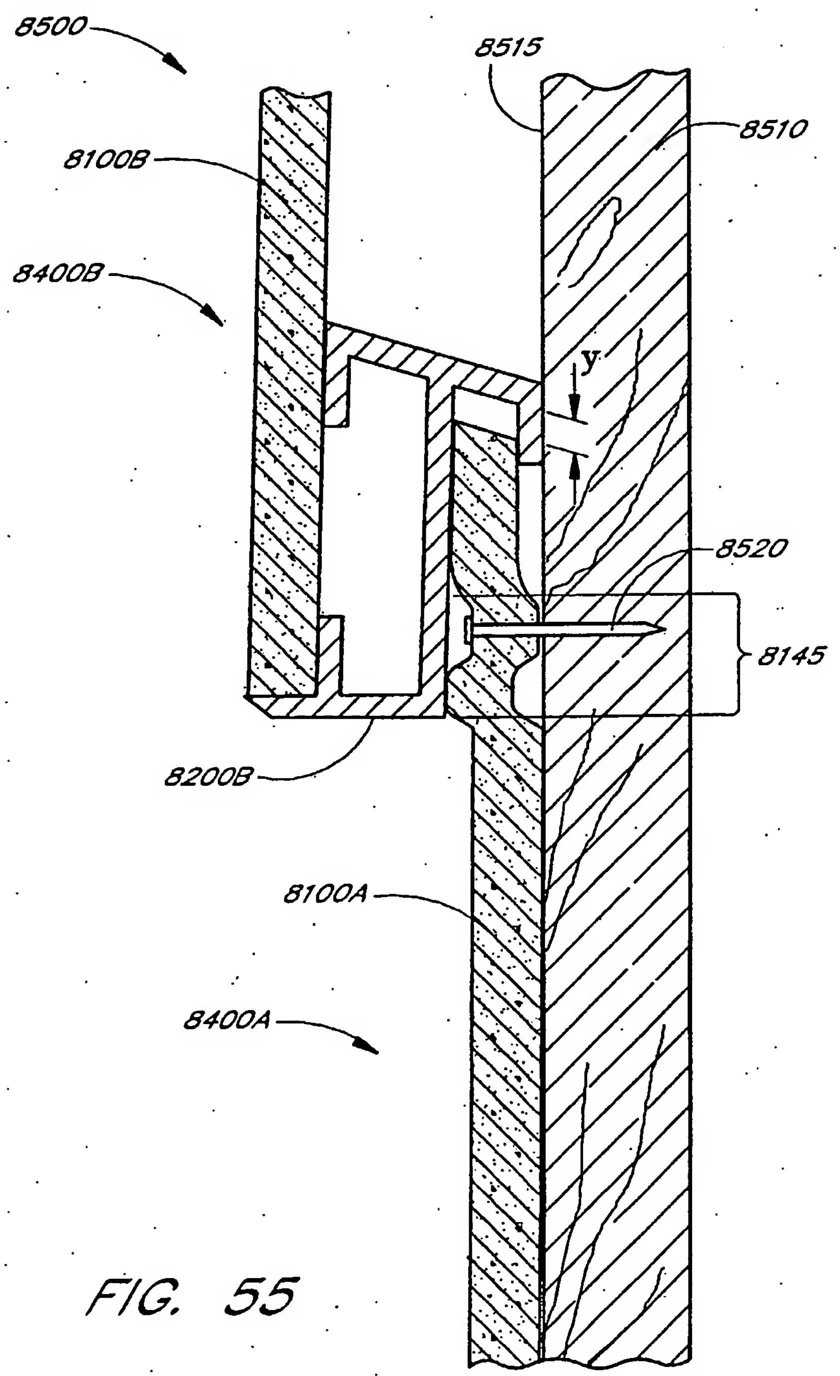


FIG. 55

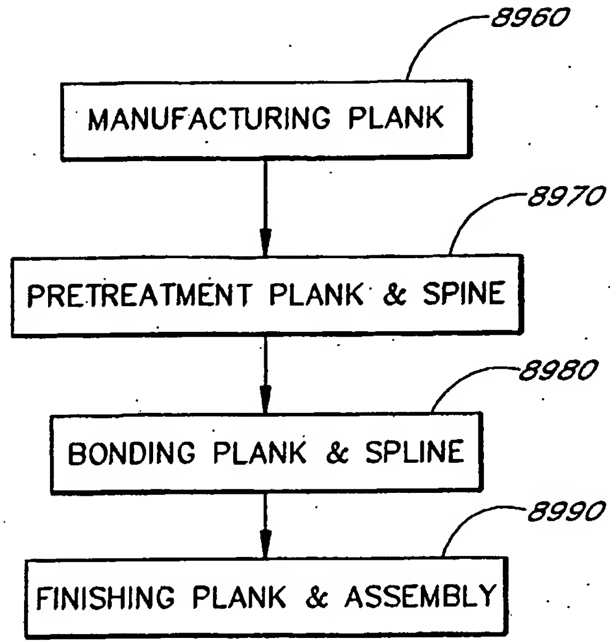

8960
MANUFACTURING PLANK
8970
PRETREATMENT PLANK & SPINE
8980
BONDING PLANK & SPLINE
8990
FINISHING PLANK & ASSEMBLY

FIG. 56

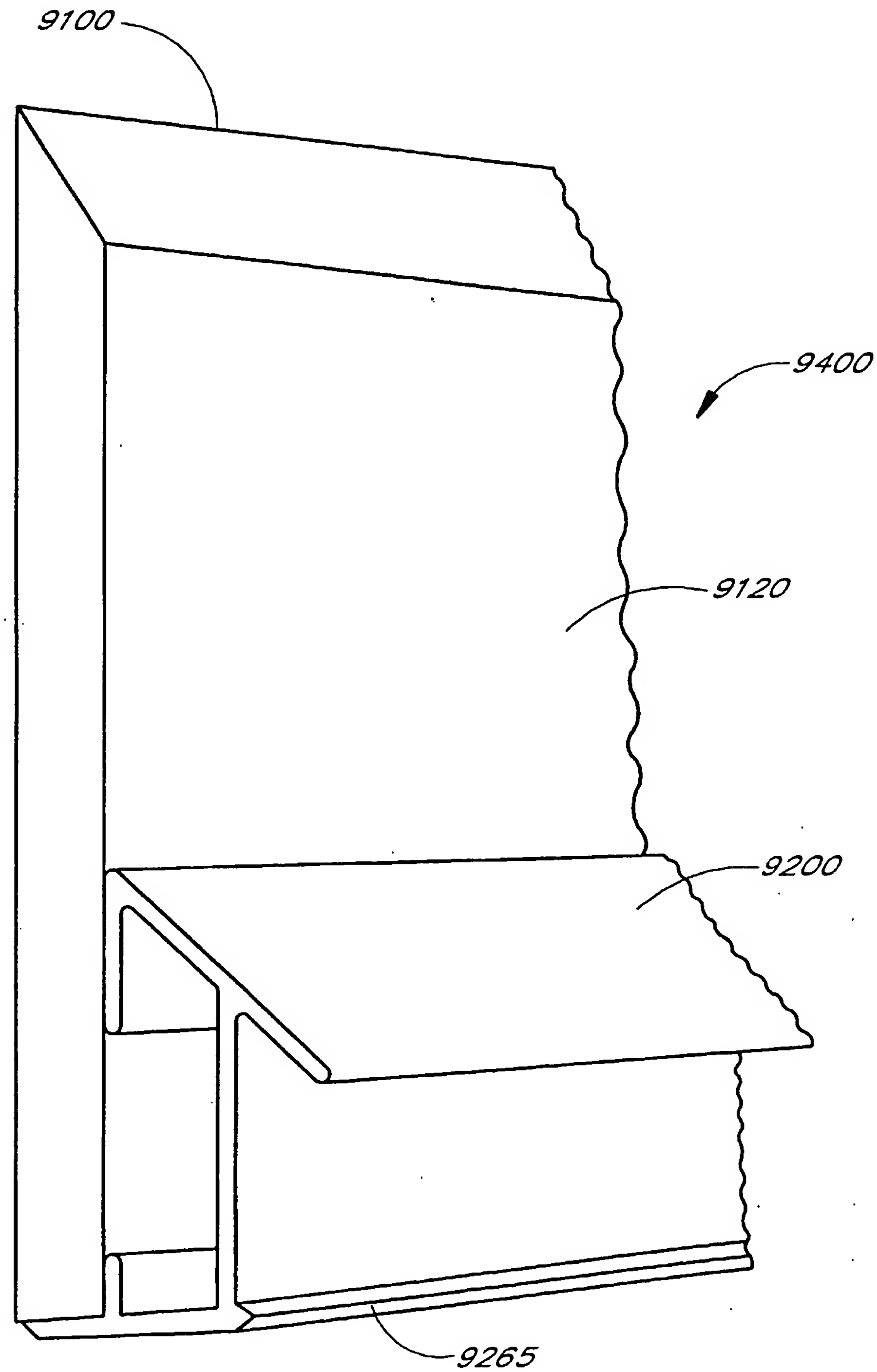


FIG. 57

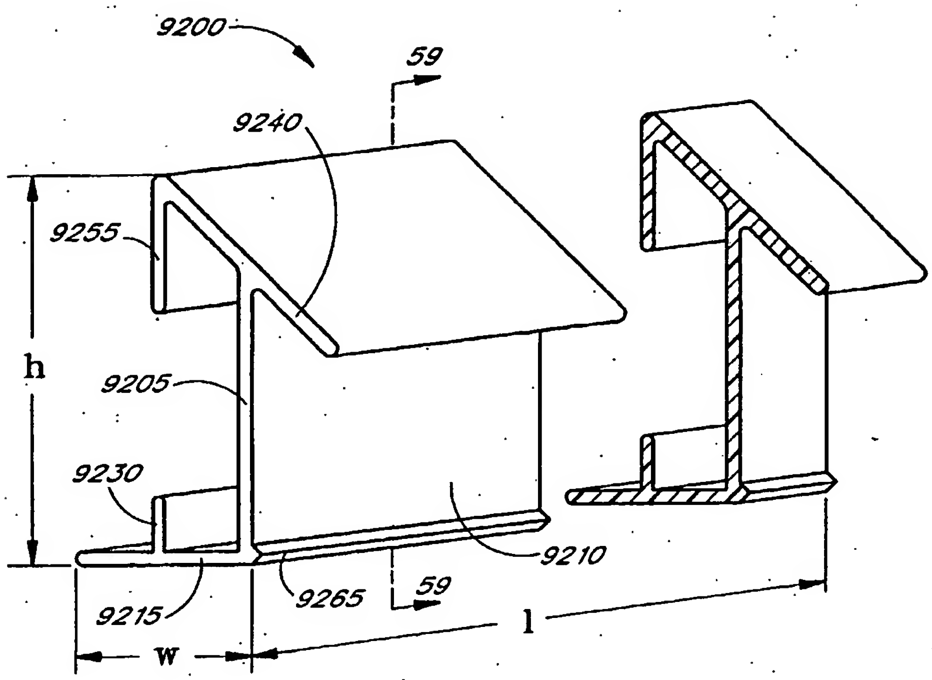


FIG. 58

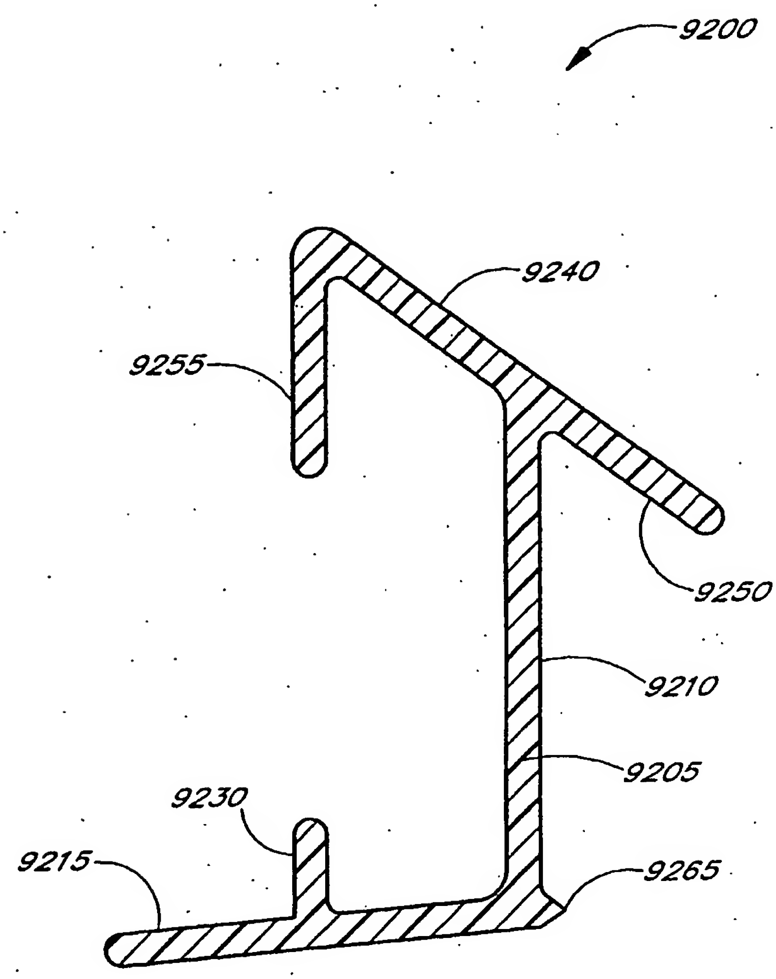


FIG. 59

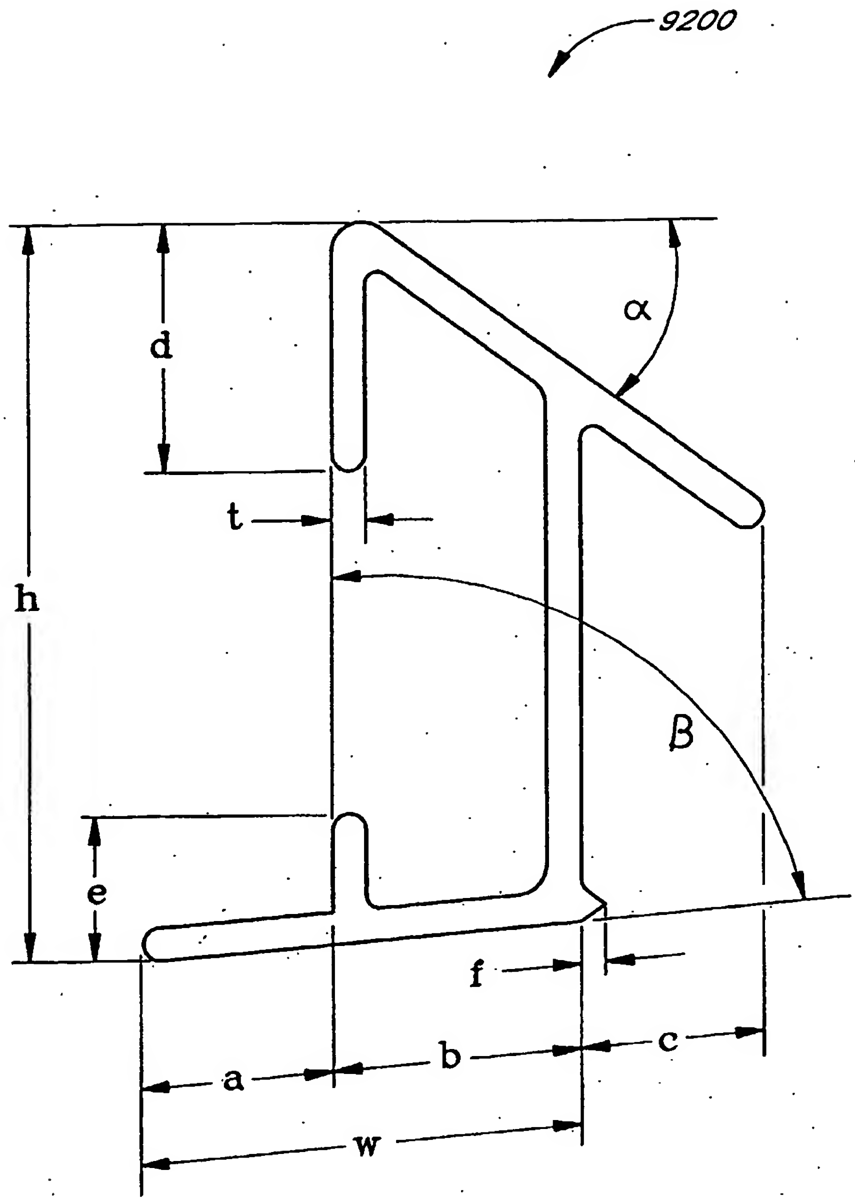


FIG. 60

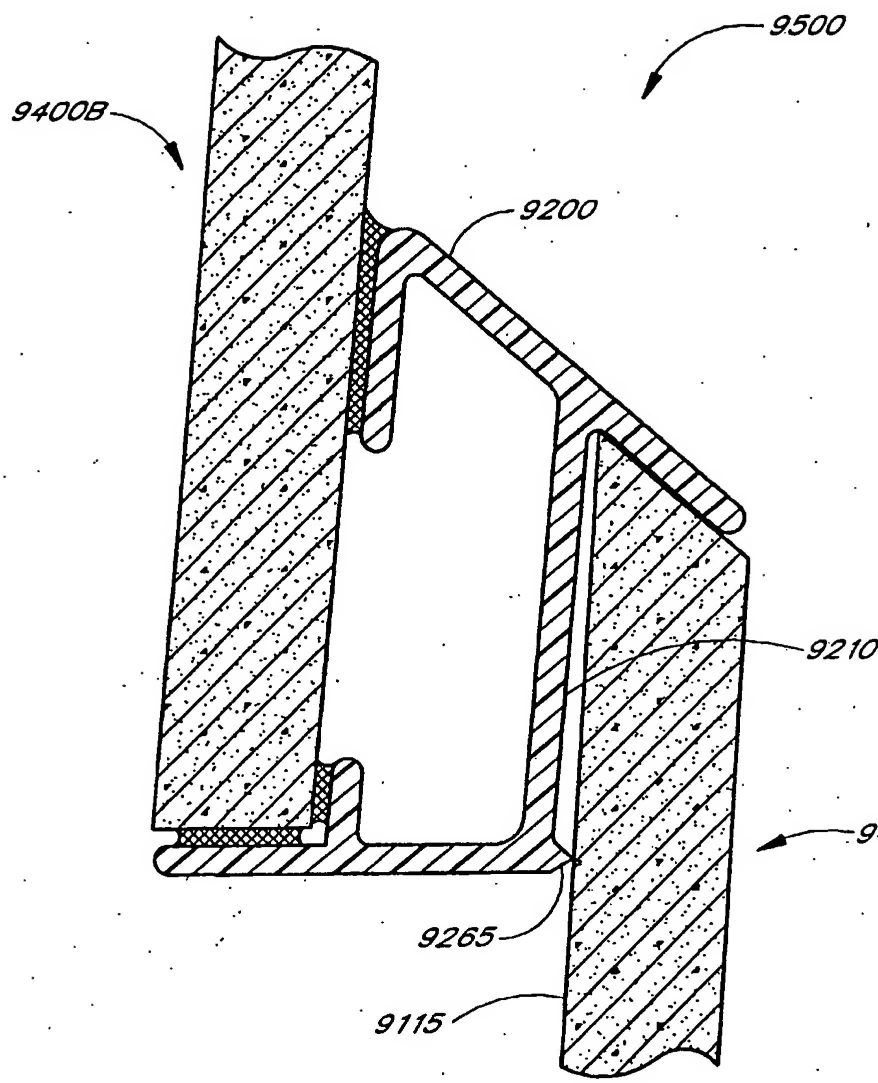


FIG. 61

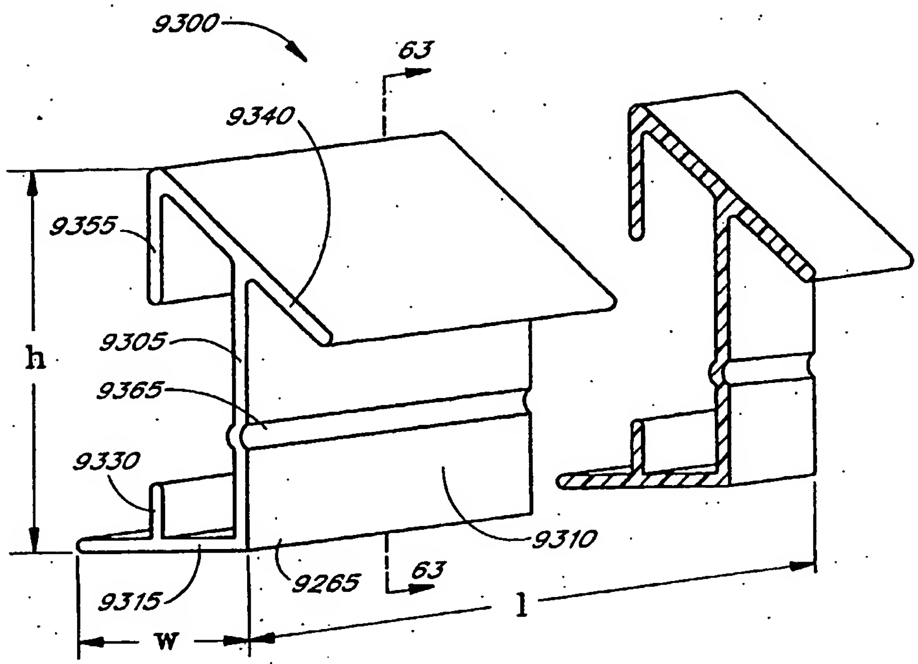


FIG. 62

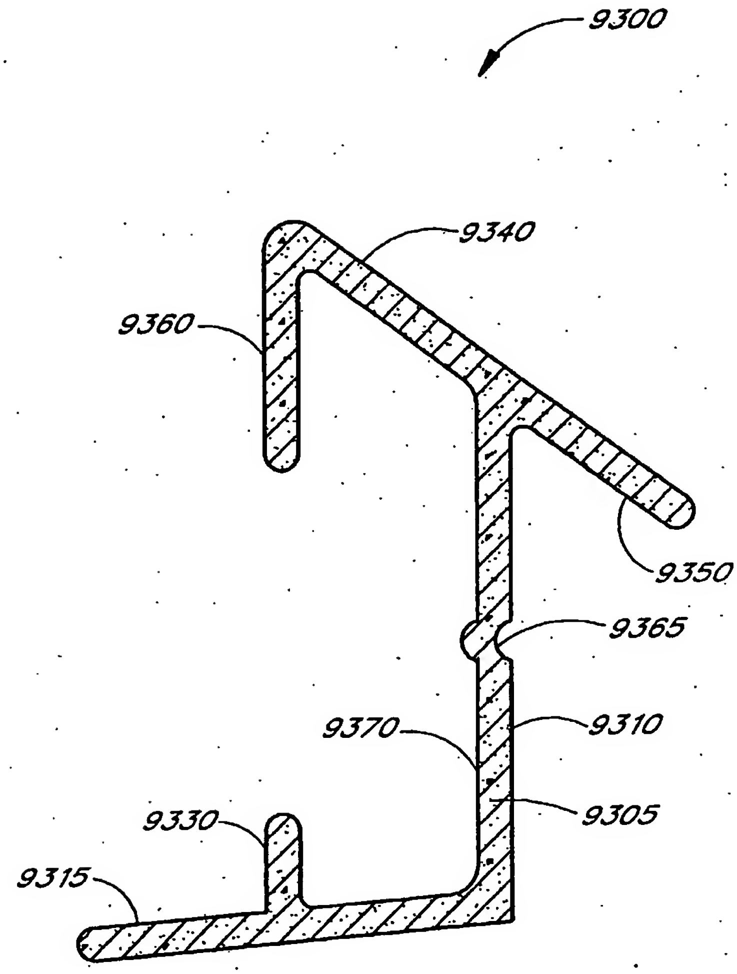


FIG. 63

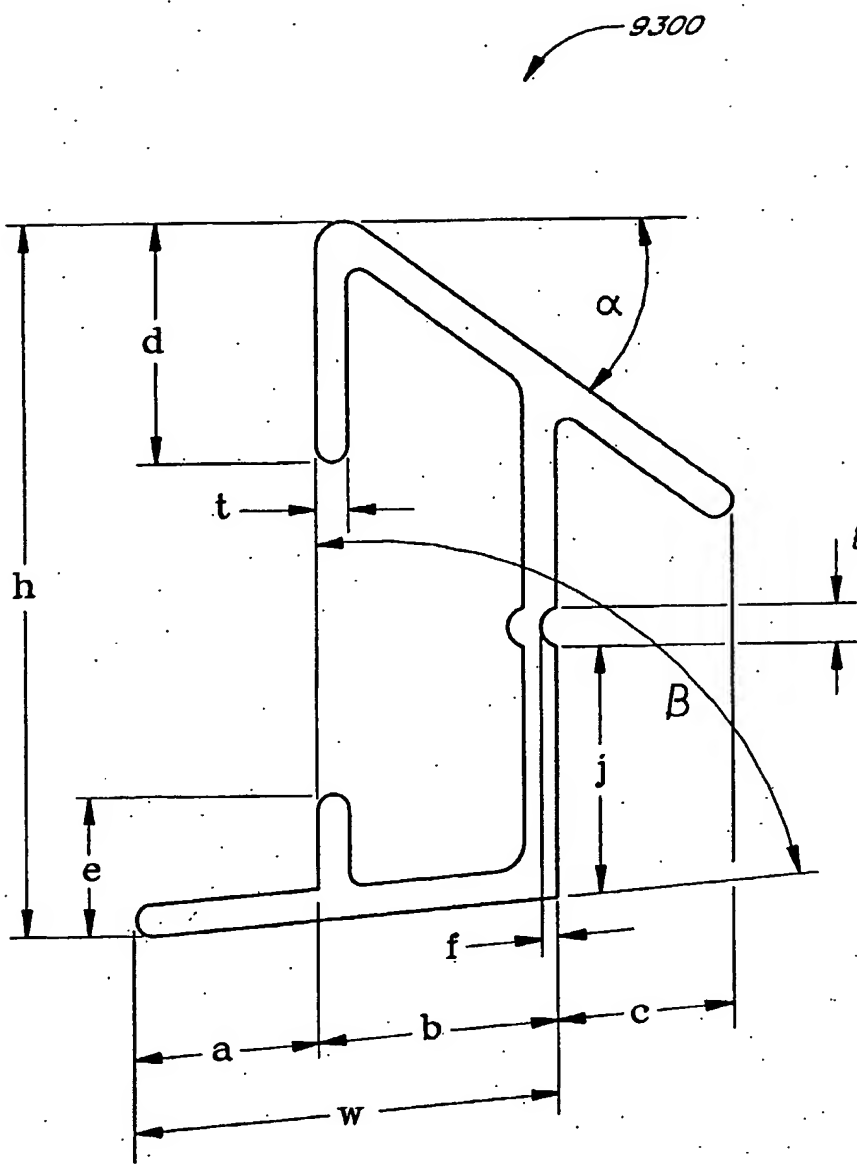


FIG. 64

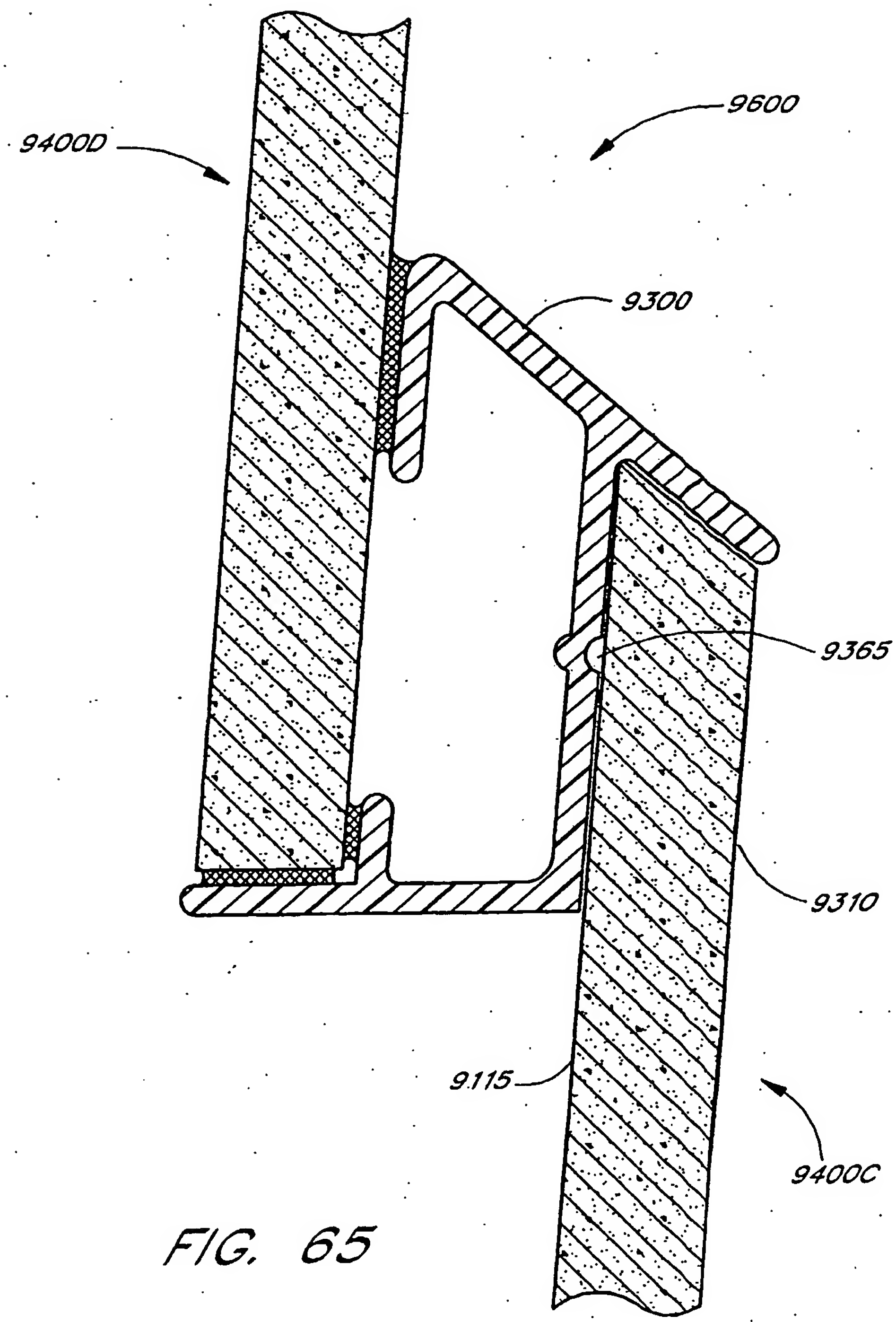


FIG. 65

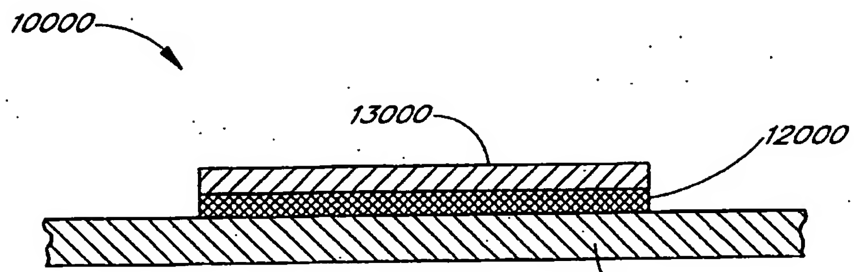


FIG. 66

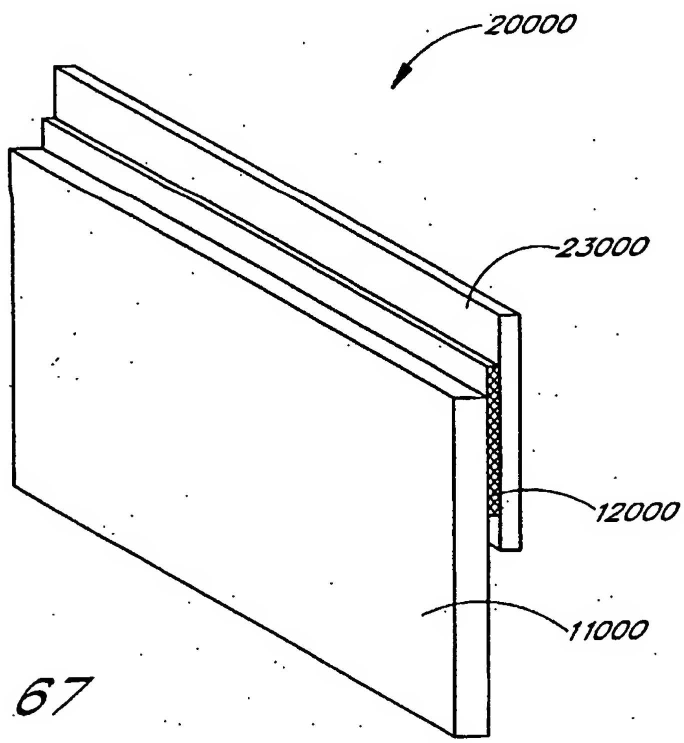


FIG. 67

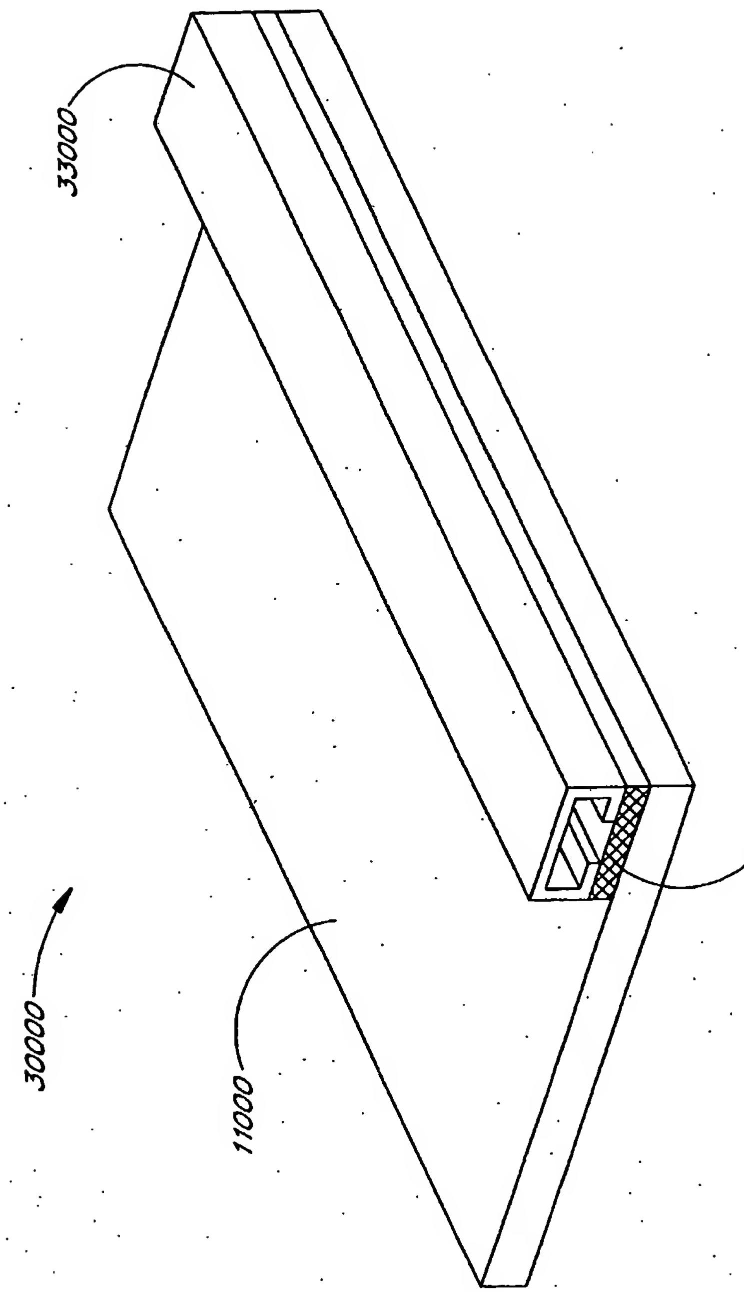


FIG. 68

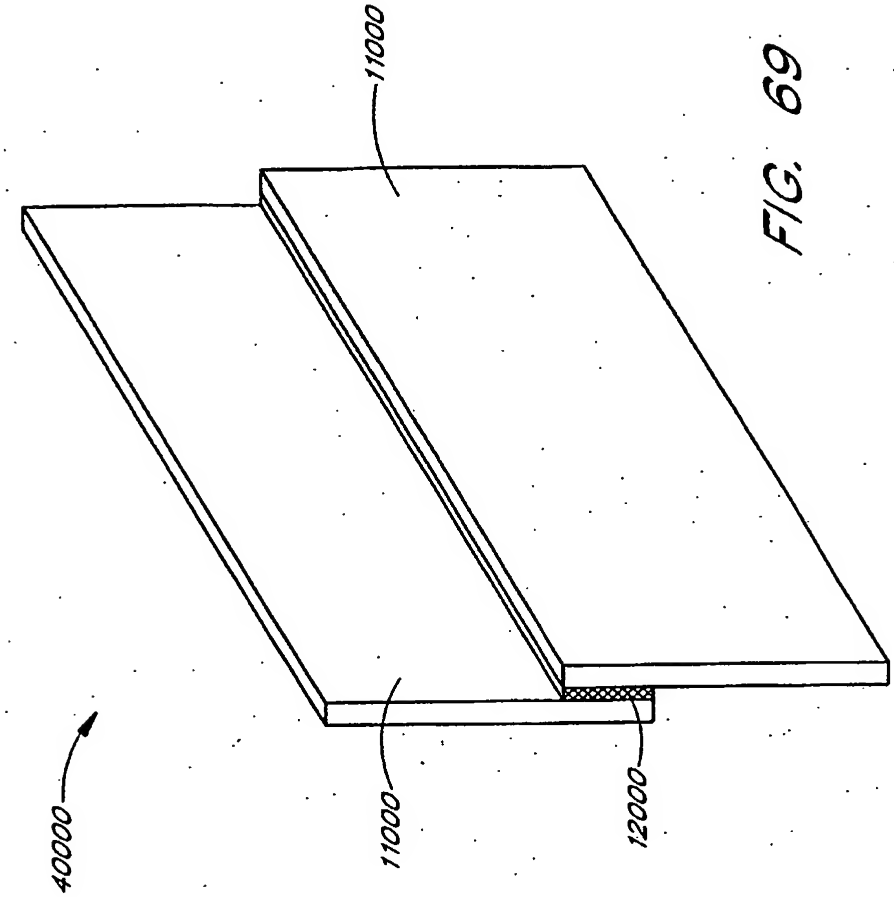
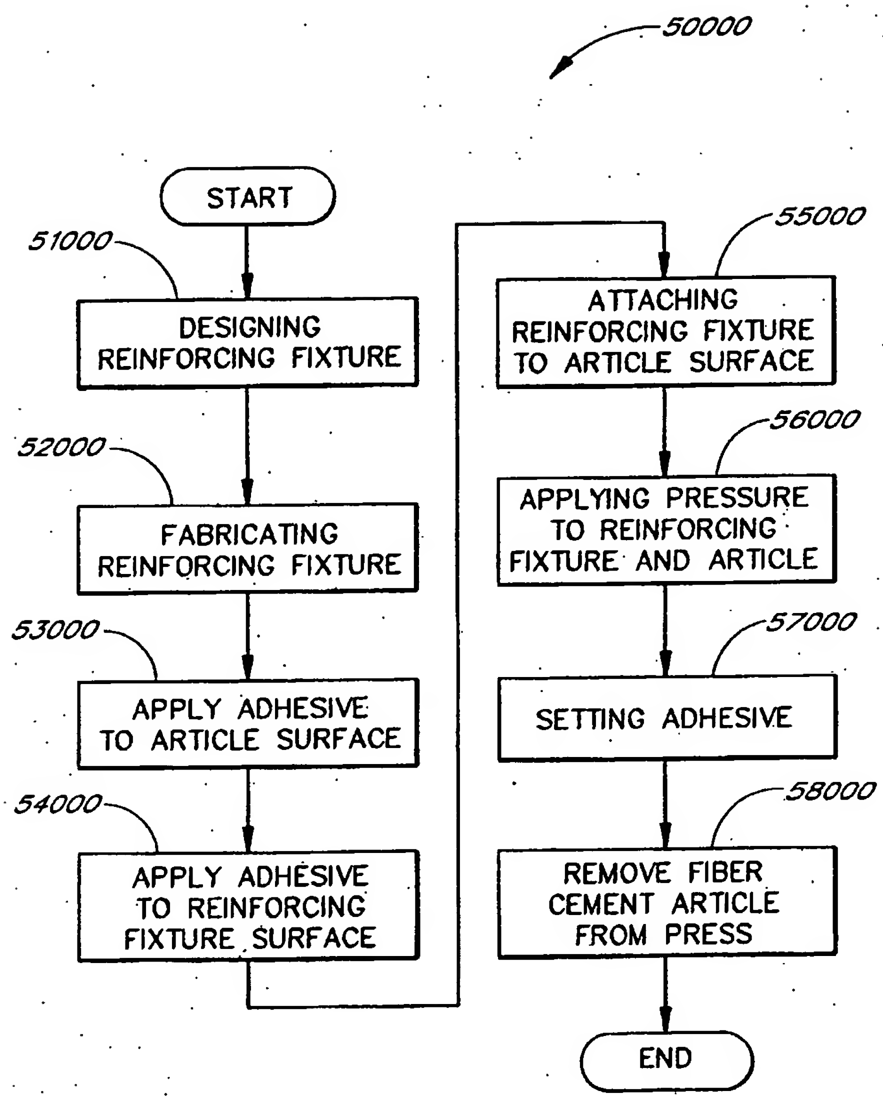


FIG. 69


50000
START
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DESIGNING REINFORCING FIXTURE
52000
FABRICATING REINFORCING FIXTURE
53000
APPLY ADHESIVE TO ARTICLE SURFACE
54000
APPLY ADHESIVE TO REINFORCING FIXTURE SURFACE
55000
ATTACHING REINFORCING FIXTURE TO ARTICLE SURFACE
56000
APPLYING PRESSURE TO REINFORCING FIXTURE AND ARTICLE
57000
SETTING ADHESIVE
58000
REMOVE FIBER CEMENT ARTICLE FROM PRESS
END

FIG. 70

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/10609

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E04F13/16 B32B13/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E04F B32B C09J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 40 04 103 A (WENDKER LEICHTMETALL U LEICHTB) 14 August 1991 (1991-08-14) column 3, line 65 -column 6, line 27; figures 1,2	1
Y		2,3
A		4-7, 12-15, 18,21, 22, 26-32,34
Y	FR 2 624 870 A (ELF AQUITAINE) 23 June 1989 (1989-06-23) page 1, line 1 -page 13, line 23; examples 1-10	2,3
A		1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"E" earlier document but published on or after the international filing date

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 August 2002	07/08/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Ayiter, J

INTERNATIONAL SEARCH REPORT

Information on patent family members

rnational Application No
PCT/US 02/10609

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
DE 4004103	A	14-08-1991	DE	4004103	A1	14-08-1991
			DE	9007749	U1	23-02-1995
FR 2624870	A	23-06-1989	FR	2624870	A1	23-06-1989
			DK	544488	A	29-09-1988
			EP	0279725	A1	24-08-1988
			FI	884484	A	29-09-1988
			WO	8805796	A1	11-08-1988
			JP	1502035	T	13-07-1989
			NO	884334	A	30-11-1988